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CANADA'S NONFERROUS METALS INDUSTRY: NICKEL and COPPER

A Special Report

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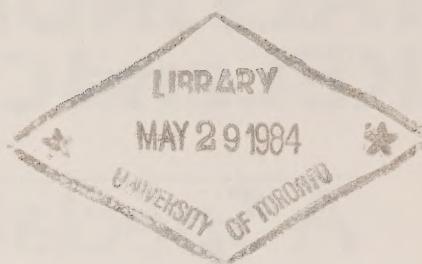
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FOREWORD

I am pleased to release this study on Canada's nickel and copper industries. While I am delighted to have been personally involved in the final stages of this initiative, I would like to acknowledge the fact that the initial impetus behind this study resulted from the efforts of my predecessor, the Honourable Judy Erola.

By way of background, in February 1983, Energy, Mines and Resources (EMR), obtained Cabinet approval and funding to undertake a comprehensive study of Canada's nonferrous metals industry. The objective of the study was to identify the elements of a Canadian strategy which would foster an internationally viable and growing nonferrous metals industry, consistent with long standing economic development and environmental goals. It was also intended to provide information and analyses to various interest groups to aid the future process of policy analysis and development.

This report is the first of two which will provide a summary of the analyses and major conclusions of the EMR-led study on Canada's nonferrous metals industries. This document deals primarily with Canada's nickel and copper industries and those nonferrous smelters in eastern Canada that are significant emitters of sulphur dioxide. The second report, which will be available in summer 1984, will examine Canada's lead and zinc industries, in addition to assessing the prospects for new greenfield smelter expansion in Canada's nonferrous industries as a whole.

The work program on which this report is based was undertaken jointly by officials of EMR and the Department of Regional Industrial Expansion, with the support of Environment Canada. I would therefore like to extend my appreciation to my colleagues the Honourable Edward Lumley, Minister of Regional Industrial Expansion, and the Honourable Charles Caccia, Minister of Environment Canada.

A consultative work group, comprising members from industry, labour and both senior levels of government, was established to serve as a forum for the review and discussion of many of the background papers generated by the work program. I would like to take this opportunity to acknowledge the substantial contributions and cooperation of the members of the consultative work group in this exercise. However, it should be noted that the overall responsibility for the analyses and conclusions presented in this report rests solely with EMR.

I hope this report will encourage open and frank dialogue on the options available to government to address the major issues confronting Canada's nickel and copper producers.



William H. Rompkey



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EXECUTIVE SUMMARY

This report provides an in-depth assessment of the international competitive position of Canada's nickel and copper producers and examines those factors which will have a bearing on the future outlook and long term viability of these important Canadian industries. Although a wide range of issues will be identified and discussed, particular emphasis will be given to those associated with the need for Canada's nickel and copper producers to implement major productivity improvement and sulphur dioxide emission control programs.

Recent years have witnessed a number of significant structural changes in world mineral markets and the pattern of these changes is imprinted on the future. Over the next 10 to 15 years, world economic growth is forecast to slow to approximately one half the rate experienced between 1945 and 1973. In addition, declining intensity of metal use in major industrialized countries, compounded with energy conservation, product downsizing, substitution and technological development have had and will continue to have a moderating influence on the demand for major non-ferrous metals. Indeed, average annual rates of growth in world consumption of copper and nickel are expected to range only between 1.2 and 1.7 per cent from 1981 to 2000. This compares to an average annual rate of growth of 4.4 to 6.0 per cent for these metals over the "golden" period of world economic growth (1946-1973) and 1.0 to 1.5 per cent realized over the 1974-1981 stagflation period.

On the supply side, expectations of high growth in the 1960s and 1970s led to considerable expansion in world production capacity of all major commodities. Much of this development took place in lesser developed countries (LDCs), which often benefited from favourable international financing arrangements. At the same time, a larger proportion of the world's nonferrous mineral production capacity became controlled by governments. In the case of copper and nickel, state-owned enterprises now control 50 per cent and 40 per cent of production capacity respectively.

The recent recession has exacerbated the effects of these structural changes. In particular, world copper and nickel markets are plagued by chronic oversupply, which has led to severe downward pressure on prices in recent years. Expectations are that it will take several years before supply/demand balances are restored in these markets.

Canada's nickel and copper producers are deeply affected by developments in the international marketplace. At present about 95 per cent of Canadian nickel production and about 75 per cent of Canadian copper production is sold in export markets. The growing importance of production from government-subsidized or government-controlled enterprises, tariff and non-tariff barriers, regional trading blocks and barter trade have limited the traditional markets available to Canadian producers. These developments also suggest that free market principles have become less important

in determining market share. The most recent recession has revealed these trends in stark detail. Because some state-controlled companies continued to produce regardless of price and cost considerations, Canadian nickel operations, among the lowest-cost producers in the world, had to bear the brunt of production cutbacks over the recessionary period 1982-83.

The situation in copper is even more tenuous. A large proportion of Canadian mine production has, in recent years, moved towards the higher end of the world cost curve. This, in large measure, is due to the growing dominance of developing countries, which, in general, have benefited from high ore grades, low labour costs, concessionary financing and, in some cases, subsidies from national governments. Exchange rate devaluations have also been important in reducing our competitors' costs. At present, over 20 per cent of Canadian copper mine production capacity is closed because current prices are not sufficient to cover costs.

Canada's "custom" copper smelters are also facing difficult market circumstances. They are suffering from an increasingly uncertain concentrate supply picture, locational disadvantages and severe competition from foreign smelters which, in certain cases, benefit from large protected domestic markets. Concentrate supply shortages and very low smelter treatment charges are expected to characterize world concentrate markets for much of the balance of this decade. Since Canada's custom smelters will have to look increasingly towards non-local sources of feed, in order to operate at high levels of capacity utilization, the competitive position of these operations is expected to deteriorate further over the next several years. Unlike the Canadian nickel industry which is better situated to weather current depressed market conditions, the problem faced by some Canadian copper mines and custom smelters is, indeed, one of outright survival.

In spite of differences in their relative cost competitive positions, Canada's nickel and copper producers and the communities dependent on them are in a more vulnerable position today than at any time in history. The market outlook is not particularly optimistic for either commodity. The industries' problems are further exacerbated by heavy debt loads and inadequate cash flows. In many cases, expenditures on exploration, mine development and research and development have been dramatically cut back in order to conserve cash. For some operations, particularly the custom copper smelters, the adequacy of local concentrate supply to support existing operations has come into question. Under these circumstances the priorities of Canada's nickel and copper producers must be to restructure balance sheets, rebuild ore reserve positions, and implement productivity improvement programs, in order to improve or at least stabilize their position in the marketplace.

Market circumstances will continue to exert tremendous pressure on Canadian industry to cut costs and increase productivity. At the same time, Canada's nickel and copper producers are being pressed to implement measures to address the problem of sulphur dioxide emissions. The nonferrous smelting industry is the largest industrial source of sulphur dioxide east of the Manitoba-Saskatchewan border. In order to achieve the recently stated objective of 50 per cent reduction in SO₂ emissions by 1994, nonferrous smelters can expect to bear a large share of the required cutbacks.

In response to these priorities, in-depth technological profiles were undertaken for five metallurgical operations. The objective of this exercise was to determine the degree to which various modernization and/or sulphur fixation alternatives, which appear feasible in the short-term, are compatible with the twin objectives of increased international competitiveness and pollution control. Longer term, higher risk technologies were examined also.

In general, the results of the analysis showed that technologies, which appear feasible in the short term, do not offer very attractive economic solutions to the problems confronting Canada's nickel and copper industries, though there are some exceptions.* In the case of relatively modern smelters facing a requirement to reduce emissions, (e.g. Inco Limited, Thompson, Inco Limited, Sudbury (copper circuit), Falconbridge Limited and Noranda Mines Limited (Horne), pollution control programs would, in most cases, result in a significant cost burden. For older facilities; e.g. Inco Limited, Sudbury (nickel circuit), Hudson Bay Mining and Smelting (copper and zinc), productivity improvements and pollution control can best be achieved through a major modernization of existing facilities. However, under present and forecast conditions, the economic benefits associated with most of these modernization programs are quite limited and do not provide adequate rates of return on the capital expenditures involved.

The total capital cost of the modernization and sulphur fixation programs studied for Canada's nickel and copper smelters approaches \$1.1 billion (1982). In addition, operating costs would increase substantially for some operations. Since the industry is a price taker in international markets, these costs cannot be passed through to consumers. Given the clouded outlook for nickel and copper markets generally and the poor financial condition of individual firms, it is unlikely that Canadian producers will be in a position to embark on major smelter improvement programs much before the late 1980s or early 1990s.

There are other complicating factors. For instance, a major modernization or emission reduction program by the nonferrous smelting industry, using technologies that are technically feasible in the short term, would result in a significant increase in byproduct sulphuric acid production. Achievement of stated environmental objectives could lead to some 1.6-1.7 million tonnes of additional sulphuric acid production per year. This acid will not be easy to dispose of. Indeed, it is quite possible that for some operations, netbacks (e.g. selling price f.o.b. smelter) realized on acid sales could fall well short of the costs of producing the acid itself. For the Manitoba smelters, the costs of producing and selling byproduct sulphuric acid represent a very strong disincentive to modernize and control emissions, using conventional technology, because of the large negative netbacks that would result from having to bear very large transportation costs to market.

* The exceptions are Hudson Bay Mining and Smelting Co., Limited (HBMS) - zinc plant modernization, and possibly Falconbridge Limited - pyrrhotite rejection.

On the other hand, there are some bright spots. The study has identified specific new or modified technologies for each operation, which offer the potential to improve productivity or make pollution control more affordable. In addition, there are promising alternatives to increase the value of the sulphur byproduct or reduce the cost of producing sulphuric acid. Indeed, for some operations, it is possible that economic solutions can be found for pressing market and environmental problems.

It is estimated that many of these promising new or modified technological alternatives could be developed and demonstrated within a five-year period or less. If test work proves successful, commercial scale implementation of these technologies could be achieved, for most plants, within the timeframe recently established by federal and provincial environment ministers. Moreover, the time spent in finding optimal technological solutions would provide companies an opportunity to restructure their balance sheets and allow producers to stabilize their position in the international marketplace.

Because of the market and financial circumstances facing Canadian nickel and copper producers, major economic dislocations could result, depending upon the timing of regulated emission reductions for nonferrous smelters. If major reductions are required at individual smelters before the early 1990s, there may be a need for new programs of capital and other forms of assistance to help offset the economic and in some cases technical shortcomings of existing technologies. In this manner the international competitive position of the industry would not be undermined or jeopardized in the pursuit of environmental objectives.

Alternatively, if emission reductions from nonferrous smelters are not required until 1994, government initiatives to encourage the development and demonstration of promising new or modified technologies could be a logical first step. The time spent in finding optimal technological solutions would provide companies an opportunity to restructure their balance sheets and to stabilize their position in the international marketplace. Although this approach would not preclude the possible need - for some capital assistance at a later date, it could offer the most cost effective route to achieve the twin objectives of increased international competitiveness and pollution control in Canada's nickel and copper industries.

The timing and apportionment of SO₂ emission reductions among industries and establishments to meet stated environmental objectives has yet to be determined. In developing an approach to achieve desired environmental goals, it is clear that decision makers will need to carefully consider matters related to market, financial, technical and byproduct sulphur issues. This will not be an easy task. It is hoped that this document will provide a useful basis and a first step towards the development and implementation of an overall strategy that will permit the timely resolution of both the economic and environmental problems facing Canada's nickel and copper producers today.

INTRODUCTION

Canada is the world's largest producer and exporter of nickel and ranks high in terms of both copper production and trade.* In 1980, the value of nickel and copper production in Canada approached \$3.4 billion, of which \$2.5 billion was sold in export markets. Canada's nickel and copper industries have become a powerful engine for job creation, export generation, capital growth and technological advancement. They also remain an important vehicle of regional economic development, primarily in remote areas of the country. Large transnational companies, mainly Canadian controlled, dominate the sector. The scale and efficiency of Canadian operations have been extremely important in achieving Canada's prominent position in trade, particularly as Canadian companies are unable to enjoy the benefits of selling into a relatively large domestic market. Past growth and performance have been achieved largely in an environment in which competition was relatively free, in which economic benefits accrued to efficient producers and in which taxation and government regulation were relatively constant.

The last 10 to 12 years have been perhaps the most tumultuous period for the industry in the post-war period. This, in large measure, has been due to the significant structural changes which have occurred in the world economy and world mineral markets, the effects of which were exacerbated in the most recent recession. The last economic downturn hit Canada's nickel and copper industries particularly hard, resulting in many plant closures and production cutbacks. Declining real prices and consequent reductions in cash flow have seriously undermined the financial position of many companies. This has led to significant reductions in mine exploration and development, research and development (R&D) and major capital expenditure programs. At the same time, Canada's market share has continued to decline in this depressed market. Producers have embarked on severe cost cutting and productivity improvement programs. Nevertheless, there remain serious concerns about the international competitiveness of our copper and nickel industries.

At a time when the industry is under tremendous pressure to cut costs and increase productivity, it is being pressed to implement pollution control programs in order to help resolve acid rain and other environmental problems. Because the industry is a price taker in international markets, concern has been expressed about the impact of more stringent regulation on the long term viability of specific operating establishments and the communities dependent on them. These concerns take on added urgency in view of the industry's financial position, the clouded outlook for commodity markets in general, and possible sulphur byproduct marketing problems.

* Canada ranks second in terms of world copper concentrate trade and third in terms of world metal trade.

The purpose of this report is to examine in depth many of the issues confronting Canada's nickel and copper producers and in so doing indicate the potential need and scope for new government initiatives. Although a wide range of issues will be identified and discussed, particular emphasis will be given to those associated with the need for Canada's nickel and copper producers to implement major productivity improvement and SO₂ emission control programs.

The paper begins with a review of the major structural changes which have occurred in the world economy and world mineral markets. This is intended to provide a broad overall context in which to examine the world nickel and copper industries, the relative competitive position of Canadian producers and their prospects for the future. Following a brief review of the major environmental issues facing the industry today, an overview of sulphuric acid markets will be provided. This will be followed by an assessment of the modernization and/or sulphur fixation alternatives, which appear technically feasible in the short term, for each of the major smelters of interest. These include: Inco (Sudbury), Ontario; Inco (Thompson), Manitoba; Falconbridge, Ontario; Noranda Horne, Quebec; Hudson Bay Mining and Smelting (HBMS), Flin Flon, Manitoba.* The corporate financial incentive and capacity to undertake these investments will then be reviewed. The paper will close with a discussion of new directions for research and development and a short section which provides some concluding observations.

* The reader should note that a detailed technical assessment of Noranda's Gaspé smelter was not undertaken, although it is considered in the market and financial sections of the paper.

CHAPTER I

STRUCTURAL CHANGES AND WORLD MINERAL MARKETS

Recent years have witnessed a number of significant structural changes in the world economy and world mineral markets. This chapter reviews the developments which have occurred in order to provide an overall context in which to examine the major issues confronting Canada's nickel and copper industries.

ECONOMIC CONSIDERATIONS

The most significant structural change which has occurred in the world economy has been the dramatic decline in world economic growth. The first oil shock in 1973 brought to a sudden end the "golden" period of world economic prosperity. Factors such as the rebuilding of Europe, the industrialization of Japan, rapid and sustained economic growth in the Third World, the post war baby boom, two major localized conflicts (Korea and Vietnam), the explosion of international trade and the development of international capital markets were no longer catalysts for economic growth. The world economy abruptly moved into a prolonged period of high inflation, high real rates of interest, lower employment levels and floundering expectations on the part of both producers and consumers. The 1973 oil price shock, therefore, was the precursor of a decade of stagflation and recession, which culminated in the 1980-82 recession, the worst since the 1930s. Western world economic growth averaged only about 2.5 per cent per annum over this period, dramatically below the 5.0 per cent annual average which characterized the "golden" years.

A number of structural changes in world mineral markets also began to have a noticeable impact at the same time that growth in the world economy began to slow. The maturing of the industrialized world resulted in a declining intensity of metal use on a per capita basis in major western countries, a trend which has not been offset by the high rate of economic growth in the Third World. In addition, the fourfold increase in energy prices initiated a downsizing of vehicles and the more careful design of their components. This resulted in a significant reduction in demand for the minerals by the automobile sector. The technological revolution further supported the trend towards miniaturization and declining mineral use. Also, new, more sophisticated alloys and substitute materials have been developed and have successfully penetrated many traditional end-use markets dominated by minerals. This has particularly been the case in copper. Finally, new environmental regulations resulted in the restricted use of key mineral-related products (e.g. asbestos and lead). The impact of these developments on world mineral consumption was dramatic. Unlike the "golden" period, where growth rates for most commodities averaged 4-6 per cent per annum, growth in world mineral consumption fell precipitously. For some commodities, world consumption has yet to reach the peak levels enjoyed some 10 years earlier.

On the supply side, expectations of high growth in the 60s and early 70s and concerns by industrialized countries over security of supply encouraged major new investment in mineral developments around the world. Much of this development took place in LDC's which often benefitted from a favourable international banking climate. Unfortunately, as the 1970s unfolded, it was too late to reverse investment decisions on these new projects, many of which had begun construction or were nearing completion. Consequently, a great deal of production capacity was brought on-stream in a period of stagnating demand.

The 1980-82 recession brought the impact of the above structural changes into sharp focus. World mineral markets were plagued by a chronic oversupply situation, and prices of most commodities fell to levels which in real terms have not been seen since the 1930s. This resulted in many mine closures in Canada and elsewhere in the world, and significant hardship for the communities dependent on them. Expectations are that it will take a number of years for supply-demand balances to be restored in world markets.

The economic recovery which started in the United States in early 1983 is now spreading throughout the rest of the world. The recovery is expected to be slow by historic standards. Major constraints are continuing high real rates of interest, financial problems in a number of industrialized and less developed countries and a worrisome increase in protectionist sentiment.

Economic growth after the world recovery is expected to be modest by historical standards. The stimulating factors inherent in the golden years will not be duplicated. Growth in the western world economy is expected to approach approximately one half the rate experienced in the 1945-73 period for the balance of the century.

The overall growth in world mineral consumption will be influenced by this moderate forecast for world economic growth. It is also expected that mineral consumption patterns will continue to be susceptible to declining intensity of metal use in major industrialized countries, to technological innovation and the development of substitute products, and to environmental concerns. The impact of energy conservation has for the most part been absorbed, but its legacy can be expected to have some bearing on metal consumption in the future. In general, the demand for most mineral commodities is expected to recover from current low recessionary levels, but the average annual rate of growth over the period 1984-2000 will be considerably lower than that experienced in the post-war period. Growth in mineral consumption is expected to be greater in developing countries than in the major industrialized countries.

Given the expected slow rate of growth in consumption, it will take several years before world demand begins to approach world production capacity levels in many commodity markets. Consequently, unless the production restraint exercised by producers becomes more widespread than it has been in recent years, surplus supply problems are likely to be a recurrent feature of many world mineral markets for much of the remainder of this decade. Under these circumstances, prices can be expected to remain low by historical standards.

INSTITUTIONAL AND MARKET CONSIDERATIONS

The changing ownership of world mineral production, the international institutional framework and continued problems of market access are matters of growing concern. Developments in these areas have undermined the function of market forces in regulating supply and demand and the effective allocation of mineral production, investment and trade.

State ownership and the growing importance of LDC's in world mineral production trade has increased considerably over the last 10 to 15 years. Due to foreign exchange and domestic employment considerations, LDC's have been less willing to reduce production when demand shrinks. There was clear evidence of this in the recent recessionary period. Because many LDC and state-controlled producers continued to produce, regardless of price, prices weakened more than in past recessionary periods. In addition, much of the cutback in world production required to restore market stability was forced onto private sector producers in industrialized countries.

Because of limited investment opportunities, LDC's are also aggressively pursuing nonferrous mineral investment opportunities. In many cases, the World Bank and other international financing institutions have facilitated development in the LDC's often at favourable financing rates. Moreover, there has been evidence that when LDC's are unable to replace their stock of capital equipment, and the national economy becomes threatened, contributions from the World Bank and other international institutions have been made available which permit modernization and restoration of mineral production levels. Developments of this nature can only exacerbate the problem of oversupply and impede the proper functioning of market forces in allocating market share. These factors can have a serious impact on the competitiveness of Canadian operations, which do not have access to these programs. Through its contributions to the World Bank and through its own Official Development Assistance (ODA) and Export Development Corporation (EDC) programs, it is often alleged that Canada subsidizes foreign mineral developments which compete directly with domestic producers. In this regard, it must be recognized that any detrimental impacts on the Canadian mineral industry must be weighed against the benefits which can accrue to other sectors of the economy and Canada's international obligations.

Relative changes in general inflation and exchange rates also have an important bearing on relative competitive positions. Although the benefits of a currency devaluation are normally dissipated by increased factor costs, industrial inefficiencies, etc., within a two to three year time period, such action can be particularly helpful in maintaining production levels during recessionary periods. Devaluations since 1981, notably by Chile, Peru and Mexico and to a lesser extent Australia, Philippines, Zaire and Zambia, have significantly improved the competitive position of producers in those countries vis à vis Canadian exporters.

The problem of market access is another critical issue which warrants attention. Tariff cuts negotiated during the Tokyo Round of Multilateral Trade Negotiations are still being phased in and will only be fully implemented in 1987. Despite these efforts to liberalize world

trade, tariffs in general, tariff preferences and non-tariff measures maintained by our trading partners inhibit or distort the export of Canadian produced metals. Generally speaking, ores and concentrates trade worldwide duty free, while smelter and refinery products face progressively higher tariffs. The situation varies by metal and by country. For example, Japan uses its tariff on refined metal imports to support higher domestic prices. This gives Japanese smelters an advantage in bidding for concentrates, and can confer a benefit to mines exporting concentrate. However, this policy encourages imports of raw materials in concentrate rather than metal form. In addition, newly industrialized countries (NICs), such as Brazil, Taiwan and South Korea, have followed the Japanese model, but with substantially higher levels of tariff and other forms of protection, and consequently greater domestic metal price premiums. These domestic price premiums can reach up to almost 100 per cent in the case of Brazil.

Ten developed countries and the European Economic Community (EEC) also grant preferential tariff access for nonferrous metals to most Third World countries under a Generalized System of Preferences (GSP). In most instances, Third World countries are accorded duty-free entry, subject to quantitative limitations after which Most Favoured Nation (MFN) rates apply. The last decade or more has also seen a movement towards economic and political regionalism. This has been reflected in the formation of various regional, political and consultative organizations which are often supplemented by regional trading, and sometimes financial, arrangements. The Lomé Convention which provides special trade and aid links between the EEC and former colonies is a notable example. Elsewhere in the world, Council for Mutual Economic Aid (COMECON) (eastern Europe), New Zealand Australia Free Trade Agreement (NAFTA) (Australia and New Zealand), Association of South-East Asian Nations (ASEAN) (southeast Asia), Caribbean Common Market (CARICOM) (the Caribbean), Latin American Integration Association (LAFTA)* and the Andean Group (South America), give further evidence of the tendency towards increased regionalism. Since Canada is not a participant in any regional trading block, marketing opportunities for Canadian producers are diminished.

On another front the financial and foreign exchange pressures felt by many countries are resulting in increased counter trade. Formerly, this was more typical of trade between socialist countries and the rest of the world but is now a growing factor between industrialized countries and developing countries and indeed between developing countries. This development hits Canada at both ends of the economic spectrum. It eliminates an opportunity for Canadian manufacturers and forecloses markets which were previously accessible by Canadian mineral producers.

SUMMARY COMMENT

Structural changes in the world economy and world mineral markets have created a number of difficulties for the Canadian mineral industry. In the short term, the industry's performance will be limited by market

* LAFTA is now Asociación Latinoamericana de Integración (ALADI).

constraints, non-market dislocations and abnormally low prices. Under the circumstances, the challenge is to maintain and enhance our international competitiveness by increasing productivity, a stronger R&D effort and aggressive exploration programs. Moreover, initiatives are necessary to restore the role of market forces in regulating supply and demand, a role that has been weakened by the growing presence of foreign governments and institutions in the marketplace. Improved market access within the framework of existing multilateral and bilateral relationships will also be fundamental to the realization of the industry's medium- to long-term potential.

In spite of current problems, the mineral sector will remain a major contributor to the Canadian economy. In the medium to long term, the sector offers good prospects for increased mineral production and trade which could provide substantial dividends to Canada in terms of employment, foreign exchange and regional development. To fulfill this potential, a comprehensive strategy involving full cooperation among federal and provincial governments, industry and labour is required. However, because the above problems and issues cut across a large number of commodities, and not just nickel and copper, they will not be further dealt within this report.

CHAPTER II

NICKEL MARKET OVERVIEW

HISTORICAL PERSPECTIVE

By 1974, western world annual nickel consumption had grown to 556 400 tonnes or 5.5 times the level of world nickel demand in 1946. This represents an average annual rate of growth of slightly over 6 per cent over this time period (see Figure 2.1). The capital goods sector accounts for two thirds of nickel demand. Consequently, the rebuilding of Europe and the industrialization of Japan, in addition to sustained worldwide economic growth, were major factors which spurred growth in world nickel consumption. Over this time period, product development research, led by Inco, was also successful in creating new uses and markets for nickel, particularly in stainless steel. Rapid growth in demand and steadily rising nickel prices, in real terms, in turn encouraged major increases in production capacity around the world (see Figures 2.2 and 2.3).

In 1950, only four countries produced nickel: Canada, New Caledonia, Soviet Union and South Africa. Canada was by far the dominant producer with a 76 per cent market share. However, now there are 26 producing countries, many of which are in the Third World. The major factors which contributed to the expansion of nickel production capacity in these countries included: technological developments in the 1950s which enhanced the viability of laterite nickel deposits; the decline in energy prices in real terms in the 1960s which was beneficial to the energy intensive laterite operations; the discovery of high quality sulphide deposits in countries such as Australia; and the limited ability of Canadian producers to expand production to meet the requirements of a rapidly growing market.

Canadian production capacity increased over this period as can be seen in Figure 2. Thompson was brought on-stream by Inco in 1960 and Inco and Falconbridge expanded their operations at Sudbury. However, additions to capacity were not sufficient to maintain market share. Consequently by 1970, the year of the highest volume of domestic production, Canada's market share had fallen to 42 per cent (see Figure 2.4).

The growth rate of nickel consumption changed abruptly after the first oil shock in 1973. This was due to the sharp decline in the overall performance of the world economy. In addition, major new uses of nickel did not emerge. The impact has been dramatic. Except for a brief period in the late 1970s, nickel consumption has yet to surpass the 1974 peak.

As in other commodity markets, nickel producers were slow to respond to the structural changes in demand. Significant new production capacity was brought on-stream, which created a severe surplus supply situation. Current nameplate capacity of finished nickel producers in the western world now stands at 802 000 tonnes. Allowing for net Comecon

exports of about 45 000 tonnes annually, world production capacity approaches 847 000 tonnes. Consequently, since the mid-1970s, except for very brief periods, nickel prices have been under severe downward pressure (see Figure 2.3).

Despite Canadian producers being highly cost-competitive, a large part of the decrease in world production which has been necessary to keep inventories in check from the mid-1970s to the present has been absorbed by our companies. At no time was this more evident than in the 1980-82 recession. In 1982, Canada accounted for 14 per cent of the world supply while domestic capacity was one third of total world capacity (see Figure 2.5).

In large measure, the swing supplier role of Canadian producers can be explained by the growing importance of LDC's in the world nickel market and the increase in state ownership and control. In 1950, about 85 per cent of world capacity was privately owned. Now the proportion stands at about 60 per cent. As additional capacity is brought on-stream in the Comecon bloc and some governments in the western world increase their ownership of production facilities, the percentage of capacity privately held will fall further.

The need for foreign exchange and employment stability can drive LDC and state controlled producers to operate and sell at any price and regardless of cost. Consequently, social rather than commercial criteria have become increasingly important in determining production decisions for many nickel producers around the world. In 1982-83, Canadian companies, despite their cost competitive advantage, had to reduce production in order to stabilize markets and prevent further declines in price. Indeed, Inco responded further by permanently closing its Guatemalan operation. Despite corrective action, nickel prices fell to very low levels. Prices have yet to recover to levels which will permit profitable operation. Consequently, Canadian producers have experienced an unprecedented period of heavy financial losses. The companies, now have considerable debt in relation to equity and all have embarked on major cost cutting and productivity improvement programs.

COST COMPETITIVENESS OF MAJOR PRODUCERS

An index of the estimated operating costs of major integrated primary nickel producers in the western world is given in Figures 2.6 and 2.7, for 1983 and 1990, respectively.* Société Minière et Metallurgique de Larymaq S.A. (Larco), as the highest cost producer, is assigned a value of 100. Operating costs of producers in the centrally planned economies have not been included, due to the limited information available and the different criteria used by these countries in determining production levels.

Nickel custom smelters and refineries were also not studied. Most of these custom facilities are in Japan and there is expected to be some reduction of these operations over time, due to the energy intensity

* Includes all direct operating costs, net of byproduct credits, and excludes interest, depreciation, amortization and corporate overhead.

of nickel processing. Sherritt Gordon Mines Ltd., which operates a small nickel custom smelter and refinery operation at Fort Saskatchewan, Alberta has also been excluded. However AMAX, which is considered a custom refiner, has been included due to its equity interest in BCL in Botswana, its major matte supplier.

Canada - Current

Canada is among the lowest cost nickel producers in the world. The high quality of the nickel sulphide deposits, which contain significant quantities of byproducts and which require less energy in processing compared to laterites, provides Canadian producers major advantages. In addition, a well-trained workforce, modern mining practices and, for the most part, modern processing facilities, all contribute to the cost-competitiveness of Canadian nickel production.

Depending upon several factors, but primarily the price of byproducts, either Inco Thompson or Inco Sudbury is the lowest cost operation in Canada. With December 1983 prices for copper of 70¢ U.S. per pound and cobalt of \$U.S. 5.75 per pound, Thompson is considered a somewhat lower cost producer. The grade of ore reserves at Thompson is 2.8 per cent nickel and 0.20 per cent copper, with minor amounts of cobalt and precious metals. In comparison, the Sudbury district (including Shebandowan) ore reserves grade 1.40 per cent nickel and 1.30 per cent copper, along with important amounts of cobalt, platinum, gold, silver and other byproducts. The Thompson nickel smelter complex is also a more modern, lower cost facility in comparison to the nickel circuit at Sudbury, which is based on 1930s technology.

Operating costs of Falconbridge are somewhat higher than Inco, due principally to higher mining and refining costs. Smelter costs are lower due to the new smelter which was completed in 1978. The grade of ore reserves is comparable to that of Inco at Sudbury, with nickel being 1.30 per cent, copper 1.00 per cent and other byproducts being of somewhat lower value.

Canada's high ranking has been achieved despite some major disadvantages. Labour costs comprise over 50 per cent of total costs of producing a pound of nickel in Canada. This is explained in part by the fact that sulphide production is more labour intensive than laterite production, due principally to underground hard rock mining methods employed for most sulphide ores versus the open-pit mining methods available for laterites. In addition, labour rates in Canada are significantly higher than in some other parts of the world. For example, an average miner in Thompson costs Inco, including benefits, about \$40 000 per annum, while a miner in a country such as the Philippines costs the employer about \$2 000-4 000 per annum. The better training and experience of domestic workers along with better equipment and technology, however, helps to reduce the effect of this tremendous wage rate differential.

Environmental regulations in Canada entail costs which some foreign producers do not have to incur. Environmental control programs, particularly SO₂ control, have raised the operating costs and capital charges at domestic operations and at times have resulted in production restrictions.

Foreign - Current

Western Mining Corporation Limited (Australia), and AMAX Inc. (United States, which processes matte obtained from Botswana and Australia) are the only other sulphide producers in the western world which were examined. The remainder are laterite producers.

Western Mining in Australia is considered to be the lowest cost foreign operation. The ore mined is high grade, with current production averaging slightly more than 3 per cent nickel and about 0.2 per cent copper. Some cobalt is also contained in the ore. Labour costs per tonne of ore mined are significantly higher than at Inco Sudbury due to more labour intensive mining techniques, characteristics of the orebody, and also higher wage rates. Smelter costs are lower because of more modern technology and the absence of emission control requirements. Refining costs are comparable to those at Inco Sudbury.

Two thirds of nickel production from major producers outside of Canada is based on laterite ores. Unlike sulphides, which can be upgraded in the milling stage to a concentrate grade of about 10 per cent nickel, laterite ore cannot be upgraded economically prior to smelting. Although open-pit mining methods are less energy intensive than underground methods, the overall result is that laterite mining and processing requires three times as much energy as sulphides. While some other costs such as labour and supplies are lower for laterite producers, these advantages are not sufficient to offset higher energy costs. Consequently, operating costs for laterite nickel are generally higher than for sulphides.

Major laterite producers are: Cerro Matoso S.A., Colombia; Falconbridge Dominicana C. par A., Dominican Republic; Société Métallurgique Le Nickel (SLN), New Caledonia; Greenvale Nickel Sales pty Ltd., Australia; P.T. International Nickel Indonesia (P.T. Inco), Indonesia; Marinduque Mining and Industrial Corporation, Philippines; FENI-Rudnici I Topilnica, Yugoslavia; and Larco, Greece. The relative position of these producers on the world cost curve is determined by such factors as ore grade and energy costs, and to a much lesser extent, labour costs.

Canada 1990*

The position of Canada as a cost-competitive producer is expected to be slightly enhanced by 1990 (see Figure 2.7). Cost cutting measures, particularly in mining, are expected to show positive results. Inco

* The reader should note that no allowance has been made for smelter modernization and/or sulphur fixation programs in Figure 2.7.

Thompson and Inco Sudbury are both expected to significantly improve their competitive position over the next six years. More specifically, the introduction of a major new open-pit mine and greater use of vertical block mining techniques are expected to lower costs at Inco Thompson considerably. At Sudbury, Inco anticipates a 50 per cent improvement in labour productivity by 1985 as a result of introducing lower cost bulk mining methods. This could reduce unit mining costs by as much as 25 per cent.

Falconbridge's operating costs, in constant dollars, are expected to be about the same in 1990 as 1983. Potential savings in new mining and hoisting techniques and equipment could be offset by increased development costs. Also, the higher quality Craig mine is not expected to be in production until the early 1990s. The Craig mine will reduce operating costs when it is brought on-stream, but total costs may not decrease due to the capital charges associated with the new mine development.

Foreign - 1990

Western Mining and the Botswana and Australian operations which support AMAX's operation do not have the same scope for cost reduction as Canadian producers, due primarily to differences in orebodies.

Operating costs of laterite producers will be particularly sensitive to the price of fuel, in particular oil and coal. At current energy prices, fuel costs, based on oil and coal, respectively, represent close to 55 per cent and 30 per cent of the operating costs for laterites. The forecast small increase, in real terms, in the price of oil will tend to increase real costs for those producers dependent upon oil. Coal prices are forecast to increase at the same pace as inflation and this will reduce the current spread in operating costs between oil-based and coal-based laterite operations, as oil-based operations currently have slightly lower costs. Laterite operations dependent on oil are Falconbridge Dominicana and SLN, and those dependent on coal are Greenvale, Marinduque and Larco. No change in the type of fuel being used by these producers is forecast by 1990.

The operating costs of Cerro Matoso are expected to be higher, in real terms, in 1990 than they are at present. Power costs are currently low at Cerro Matoso due to a favourable electric power contract, but real prices for electricity are forecast to increase by 1990. Also, the grade of ore mined will decrease by 1990.

Operating costs of Falconbridge Dominicana will also rise in real terms by 1990. The operation is currently being mined selectively and lower grade material will later have to be processed. As well, the operation is based on oil for its fuel requirement and the real price for oil is forecast to increase.

P.T. Inco is expected to be producing at a higher rate in 1990. This will be a significant factor in lowering unit operating costs, given the high ratio of fixed to variable costs at this operation. P.T. Inco's relative competitive position is expected to improve somewhat over the forecast period.

The operating costs of Greenvale, AMAX Inc., Marinduque and Larco will change somewhat by 1990 but their relative ranking is not expected to change. Larco is still anticipated to be the highest cost producer in 1990, with AMAX Inc. the second-highest.

Other Considerations

The performance of Canada's nickel industry over the last 10 years clearly indicates that being the lowest cost producer does not guarantee profitability or a growing, or even stable, market share. While current nickel prices are adequate to cover operating costs, when other corporate costs such as overhead, interest and depreciation, are added the situation is substantially altered (see Figure 2.8). Inco is the lowest cost nickel producer in the world, but for 1983 it recorded a loss of \$U.S. 235 million. In 1983, Falconbridge also reported a loss of \$C 3.5 million.

A number of other factors also impact on Canada's competitive position and the ability of our producers to market their product. For example, although Canada is the largest exporter of refined nickel to Japan, tariff barriers, which are designed to protect Japanese industry, restrict market penetration by Canadian producers into this large market. Brazil has adopted similar tactics to protect its relatively new nickel industry and Canadian sales have been adversely affected.

Some new capacity has been brought into production in various parts of the world, at least partially due to favourable financing being available from certain international agencies such as the World Bank and its affiliates. The recently completed Cerro Matoso ferronickel project is an example of this. The current overcapacity in the industry is partly a result of deposits which were brought on-stream in the past decade with the assistance of these loans.

OUTLOOK*

Demand

The demand for nickel in the western world is expected to grow at 1.75 per cent per annum over the period 1981-1990 and 1.6 per cent from 1991-2000. By the year 2000, total western world nickel consumption could approach 658 000 tonnes. This compares to a level of 485 000 tonnes in 1983 (see Table 2.1).

The main factors underlying this slow-growth forecast are the maturing of the nickel market and the moderate growth forecast for the western world economy. Again no major new uses for nickel are expected. Currently, only limited resources are being committed to product development and this will have an impact on future consumption. There are few

* What follows is EMR's forecast for the world nickel market. As with all forecasts there is uncertainty in trying to predict the future.

substitutes for nickel at the present time. However, developments in ceramics, plastics and glassy metal could affect nickel markets over the longer term.

Supply

World nickel markets are expected to continue to be plagued by chronic surplus capacity over the period 1983-2000 (see Table 2.2). Although there are several deposits in different parts of the world which could be developed under suitable conditions, expected supply/demand conditions will not encourage much new development.

In Cuba, the Punta Gorda project is under development and production is expected by 1985 or 1986. The operation, with a capacity of 30 000 tonnes per year of contained nickel, was originally scheduled to commence production in 1981. However, the start-up date has been set back for various reasons, including technical problems. The 30 000-tonne Las Camaricocas project is also planned for development sometime in the late 1980s or early 1990s.

The Soviet Union has plans to increase substantially the capacity of Norilsk. The current status of these plans is not known. However, it is ironic that the final decision on this expansion could be determined by considerations related to copper rather than nickel. The Norilsk deposits particularly the large new Oktybar mine, are rich in copper, and the Soviets may want to increase production to reduce their requirements for copper imports. Copper is in short supply in the Soviet Union.

In the western world there is not expected to be much new nickel capacity developed. It is forecast that P.T. Aneka Tambang in Indonesia will add to its ferronickel capacity, with an additional 15 000 tonnes to be completed by 1990. In the 1990s there could be some new capacity added in certain other countries but the total additional capacity is not expected to be large, since the forecast nickel price will encourage only certain high quality projects, or ones with special circumstances, to come into production.

Canadian Production

Canadian production in the next few years is expected to rebound significantly from the depressed level of 89 000 tonnes recorded in 1982. Canadian producers took a disproportionate share of the worldwide cutbacks necessary to keep inventories under control and it is expected that the Canadian producers, in the next few years, will be regaining some of their lost production share (see Table 2.3).

For Inco, forecast production volumes at Thompson are expected to increase from 32 000 tonnes in 1983 to 50 000 tonnes in 1989 and hold at that level for the remainder of the forecast period. The Thompson open pit, which is planned for production in 1986, will reduce operating costs significantly. This, in combination with the current cost structure, will make the Thompson operation very cost-competitive.

At Sudbury, productivity improvements in mining are expected to further lower unit costs. This could enable Inco to capture a larger share of the market. Nickel production at Sudbury should climb from 68 000 tonnes to 105 000 tonnes in 1990 and 111 000 tonnes in the year 2000.

For Falconbridge, considerable mine development work is required before production can begin to approach the design capacity of the smelter (45 400 tonnes per year). Given the financial demands on the company and the projected nickel price, it is not expected that Falconbridge will reach capacity production before the end of the forecast period (see Table 2.3).

Prices

The overcapacity situation which currently exists is expected to persist through the 1980s and into the latter part of the 1990s and this will keep prices under pressure. Considerable idle capacity exists which could be reactivated if prices increase substantially.

Net exports from the Comecon bloc will also add to the supply and tend to lower prices. There is potential for substantial increases in capacity in these countries and the increases could well be in excess of internal Comecon consumption requirements. The excess could be available for sale to western nations, although it is not clear what impact the U.S. embargo on Cuban, and more recently, Soviet nickel will have on this situation.

Producers are expected to continue to work towards increasing their productivity, which should result in lower costs of production, in constant dollar terms. Some producers are also expected to continue to produce for reasons which do not completely reflect market forces and this will continue to keep potential supply high, and prices somewhat lower. Nevertheless, a price increase is required over current levels or some producers, because of financial constraints, will be forced to close down. The price of nickel is therefore forecast to increase with the economic recovery, from the current \$U.S. 2.20 (in 1982) per pound to \$U.S. 2.90 by 1988, and be maintained at that level in real terms for the balance of the forecast period (see Table 2.4).

SUMMARY COMMENT

The recent performance of Canada's nickel producers demonstrates the vulnerability of this important Canadian industry. The last few years have clearly shown that being among the lowest cost producers in the world no longer guarantees high levels of production, market share or profitability. A priority of Canadian companies must be to improve productivity and streamline their operations. Fortunately such programs are well advanced, but it will likely take several years before the industry has recovered from the major losses it has sustained in the recent recessionary period.

TABLE 2.1

	Demand - Probable Scenario (000 tonnes)																	
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
United States	111.0	122.0	131.0	138.0	145.2	148.8	151.5	154.2	156.4	158.6	160.8	163.0	165.3	167.6	170.0	172.4	174.8	177.2
Japan	120.0	130.0	131.0	135.0	137.0	139.4	139.2	138.8	140.0	140.3	141.0	141.6	142.5	142.8	143.2	144.4	145.1	144.9
Western Europe	205.0	220.3	214.5	210.2	200.9	205.5	209.6	213.6	217.7	221.7	225.9	230.2	234.5	238.9	243.4	248.0	252.6	257.4
Africa	6.0	6.4	6.8	7.2	7.6	8.0	8.2	8.5	8.7	9.0	9.3	9.6	9.8	10.1	10.4	10.8	11.0	11.4
Central & South America	13.0	14.0	15.0	15.9	16.5	17.3	18.5	19.5	20.4	21.3	22.3	23.3	24.4	25.5	26.6	27.8	29.0	30.3
Canada	9.5	9.7	10.0	10.2	10.4	10.6	10.8	11.0	11.1	11.4	11.6	11.8	12.0	12.2	12.4	12.6	12.8	13.0
Australia	4.5	4.6	4.7	4.7	4.8	4.8	4.9	4.9	5.0	5.0	5.1	5.1	5.2	5.2	5.3	5.3	5.4	5.4
Exports to Comecon	10.0	10.0	10.0	11.0	11.0	11.0	11.0	12.0	12.0	12.0	13.0	13.0	14.0	14.0	14.0	15.0	15.0	15.0
Other Western World	16.0	16.0	17.0	17.8	18.8	19.6	20.3	19.6	20.2	22.7	23.5	24.4	25.3	26.2	27.2	28.2	29.3	30.4
Total	495.0	533.0	540.0	550.0	560.5	565.0	575.0	583.5	583.0	593.0	602.0	612.5	622.0	632.0	642.5	652.5	663.5	673.0

Source: Mineral Policy Sector, EMR.

TABLE 2.2
Mine Production* - Probable Scenario
(000 tonnes)

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Canada	122.0	170.0	174.0	177.0	184.5	186.0	189.0	190.5	191.0	192.0	192.5	193.5	194.5	196.0	197.0	198.0		
Australia	72.0	75.0	77.0	80.0	80.0	80.0	80.0	80.0	82.0	85.0	85.0	88.0	88.0	90.0	90.0	90.0		
New Caledonia	45.0	45.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0		
Indonesia	35.0	40.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0	45.0		
Philippines	20.0	20.0	25.0	28.0	28.0	28.0	28.0	28.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0	29.0		
South Africa	22.0	23.0	24.0	25.0	26.0	28.0	30.0	33.0	33.5	34.0	34.5	35.0	35.5	36.0	37.0	37.5	38.0	
Botswana	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0	39.0	
Other Western World	92.0	108.0	90.0	87.0	86.0	91.0	92.0	100.0	106.0	117.0	121.0	127.0	136.0	144.0	151.0	159.0	167.0	
Net Comecon Exports	37.0	37.0	40.0	43.0	43.0	45.0	47.0	47.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0	50.0		
Total	470.0**	533.0	54.05	550.0	560.5	565.0	575.0	583.5	593.0	602.0	612.5	622.0	632.0	642.5	652.5	663.5	673.0	684.0

* Recoverable nickel. ** A net reduction of 25 000 tonnes in producer, LME and consumer stocks in 1983 resulted in mine production being lower than consumption.

Source: Mineral Policy Sector, EMR.

TABLE 2.3
Canadian Mine Production - Probable Scenario

Year	Inco		Falconbridge		Total
	Sudbury	Thompson	Sudbury (tonnes)		
1983	68 000	32 000	25 000		125 000
1984	100 000	38 500	31 500		170 000
1985	101 000	41 000	32 000		174 000
1986	102 000	42 000	33 000		177 000
1987	103 000	45 000	33 500		181 500
1988	103 000	49 000	34 000		186 000
1989	104 000	50 000	35 000		189 000
1990	105 000	50 000	35 500		190 500
1991	105 000	50 000	33 000		188 000
1992	105 000	50 000	33 000		188 000
1993	106 000	50 000	34 000		190 000
1994	106 000	50 000	34 000		190 000
1995	106 000	50 000	35 000		191 000
1996	107 000	50 000	35 000		192 000
1997	108 000	50 000	35 000		193 000
1998	109 000	50 000	36 000		195 000
1999	110 000	50 000	36 000		196 000
2000	111 000	50 000	37 000		198 000

Source: Mineral Policy Sector, EMR.

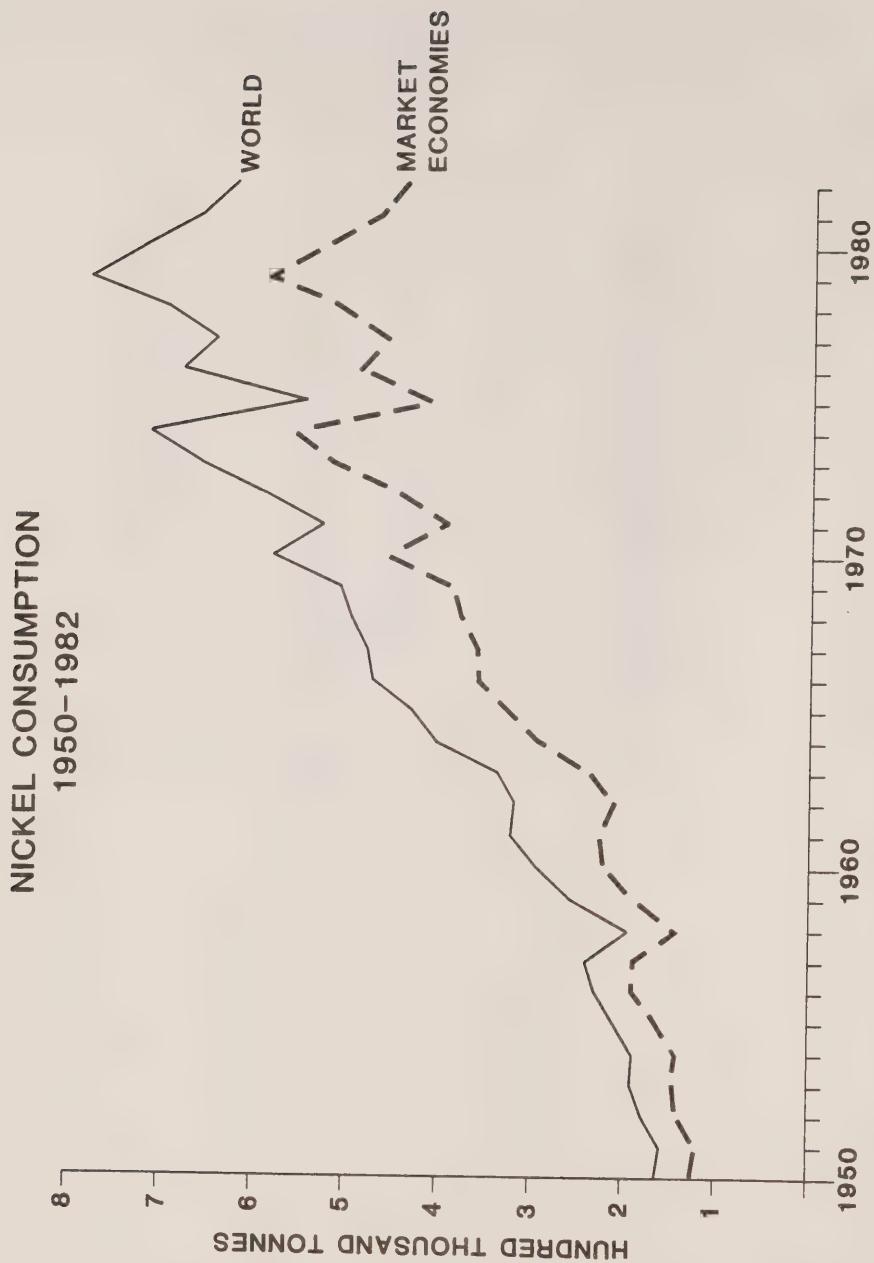
TABLE 2.4

Electrolytic Nickel
Price Forecast - Probable Scenario

	Price (constant 1982 \$US)
1983	2.20
1984	2.40
1985	2.50
1986	2.65
1987	2.80
1988	2.90
1989	2.90
1990	2.90
1991	2.90
1992	2.90
1993	2.90
1994	2.90
1995	2.90
1996	2.90
1997	2.90
1998	2.90
1999	2.90
2000	2.90

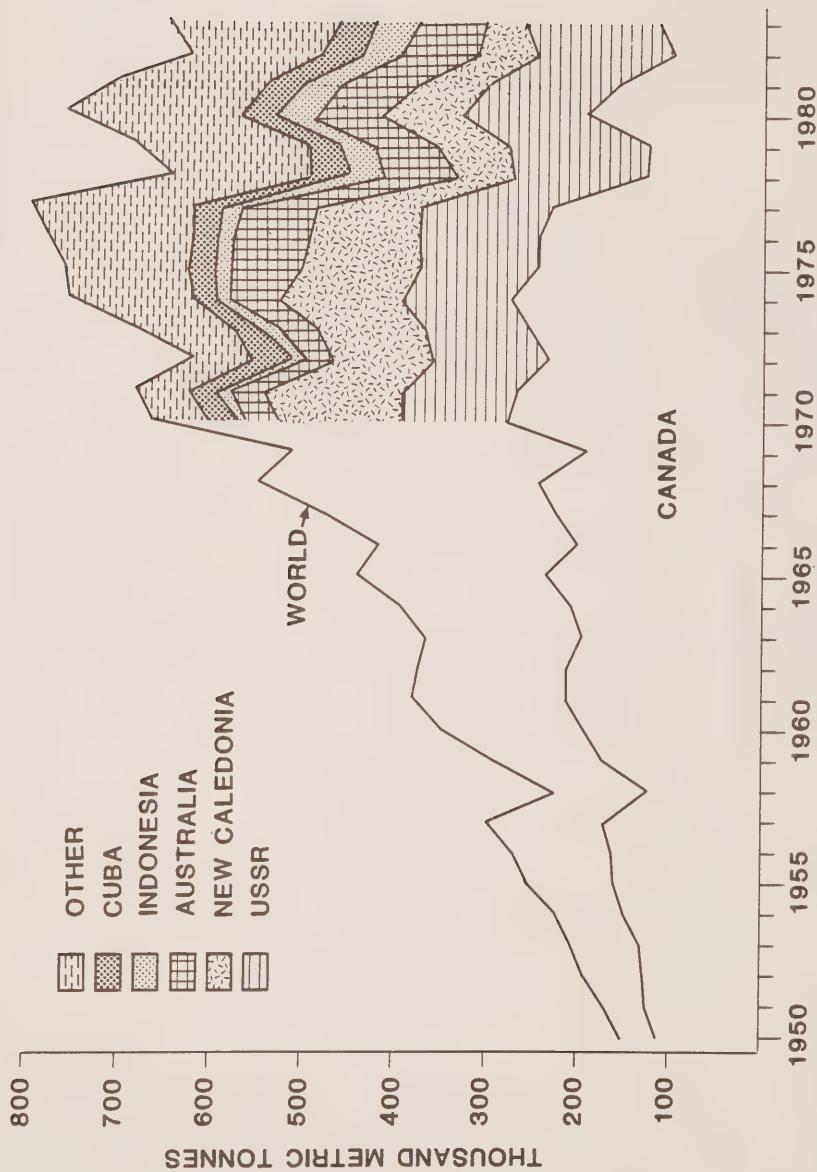
Source: Mineral Policy Sector, EMR.

FIGURE 2.1



SOURCE: Mineral Policy Sector, EMR.

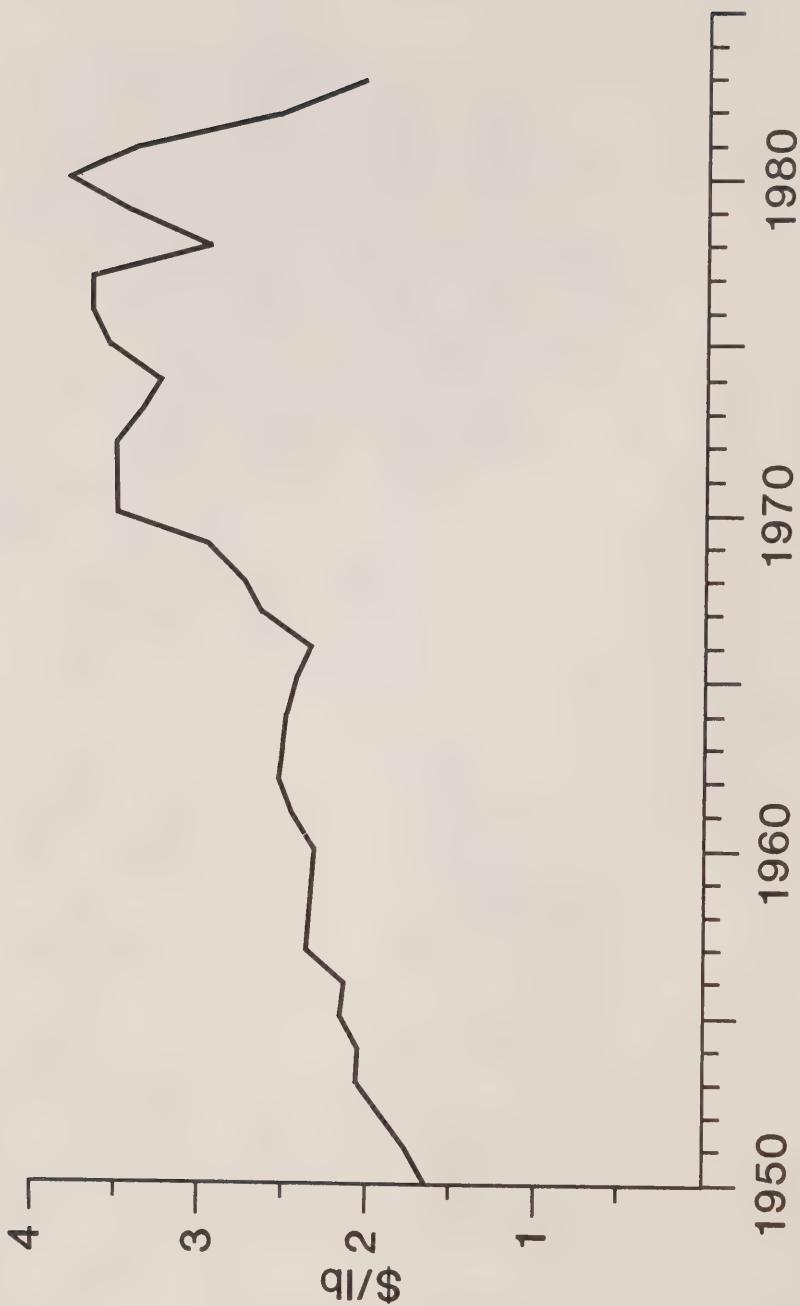
FIGURE 2.2
PRODUCTION OF NICKEL



SOURCE: Mineral Policy Sector, EMR.

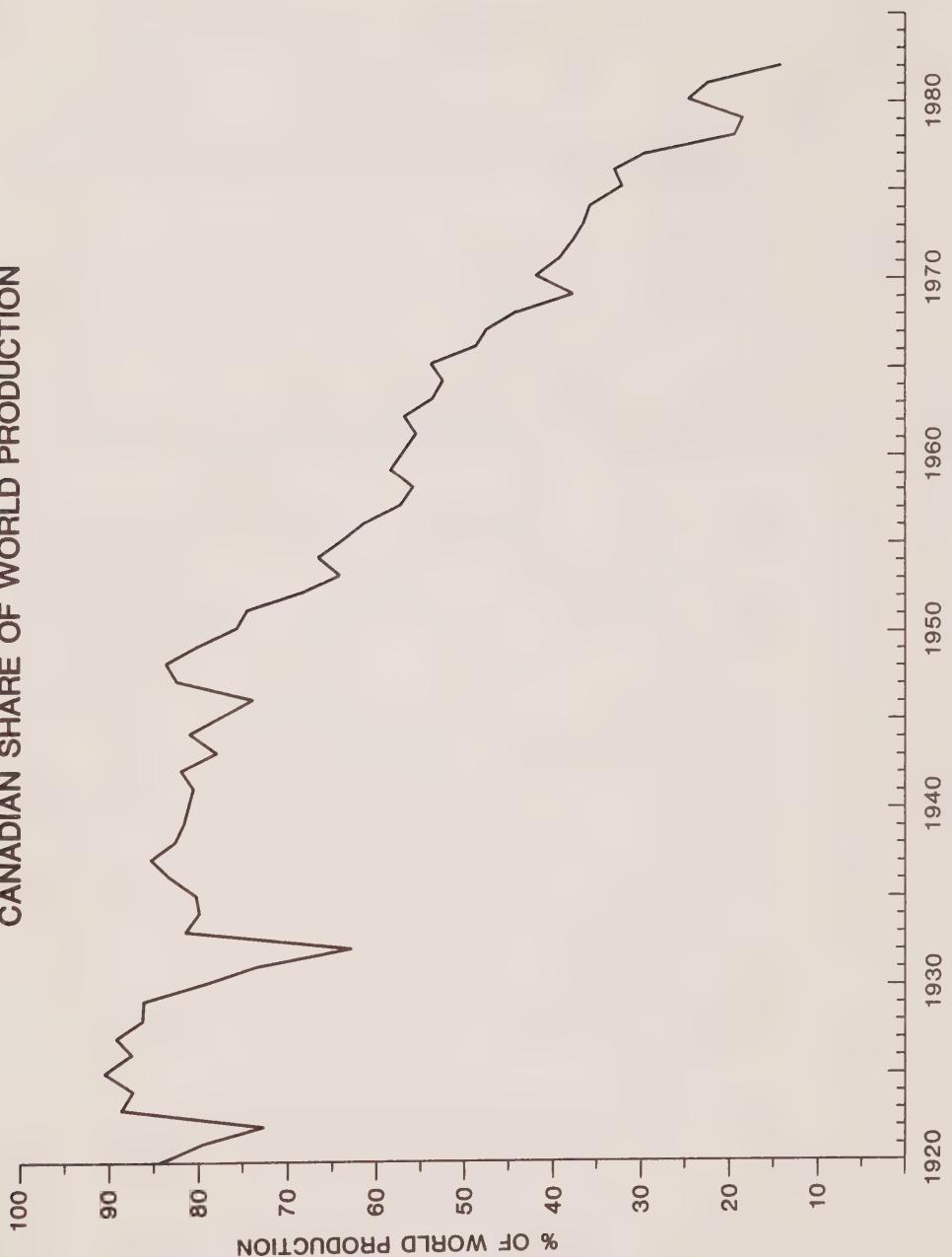
FIGURE 2.3

NICKEL PRICES
constant \$ US 1982



SOURCE: Mineral Policy Sector, EMR.

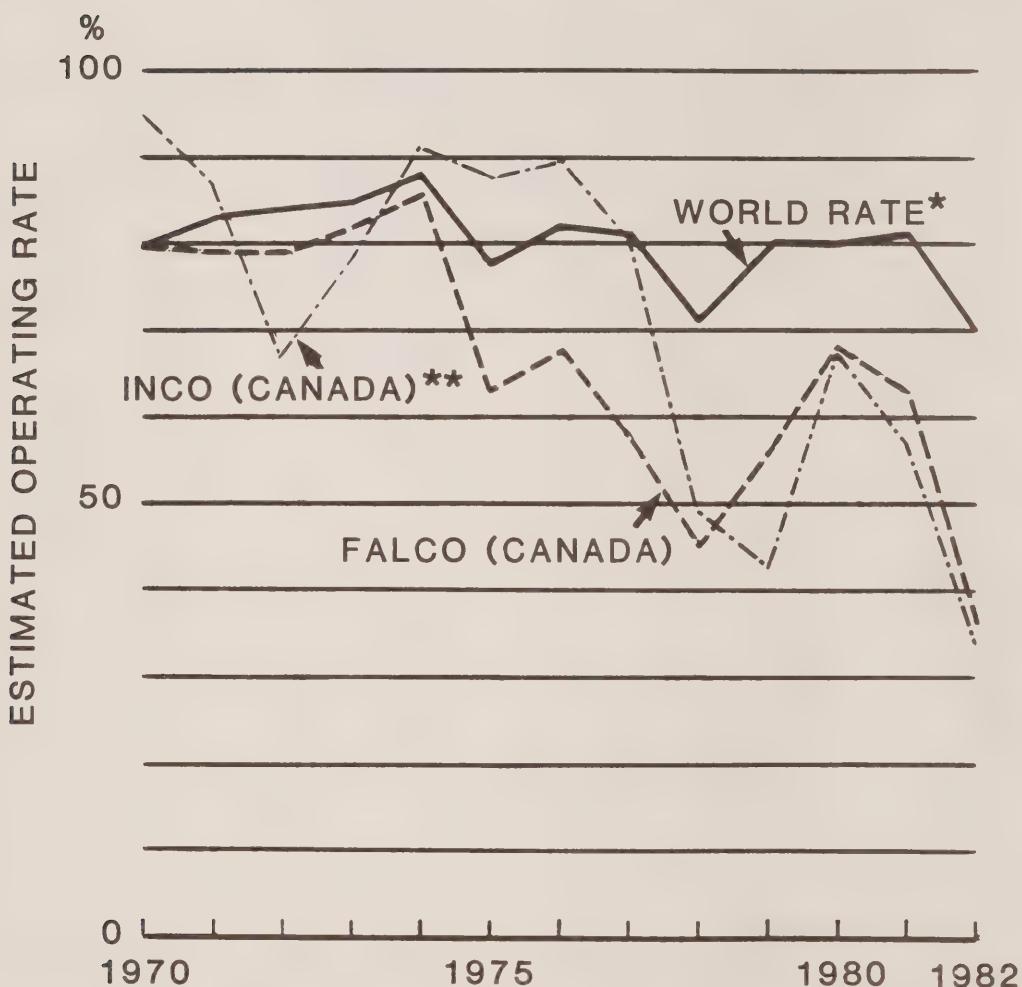
FIGURE 2.4
CANADIAN SHARE OF WORLD PRODUCTION



SOURCE: Mineral Policy Sector, EMR.

FIGURE 2.5

COMPARATIVE OPERATING RATES



* Excludes Canadian operations of INCO and FALCO

** Capacity constrained by environmental regulations since September 1980

SOURCE: Mineral Policy Sector, EMR.

FIGURE 2.6
1983 OPERATING COSTS

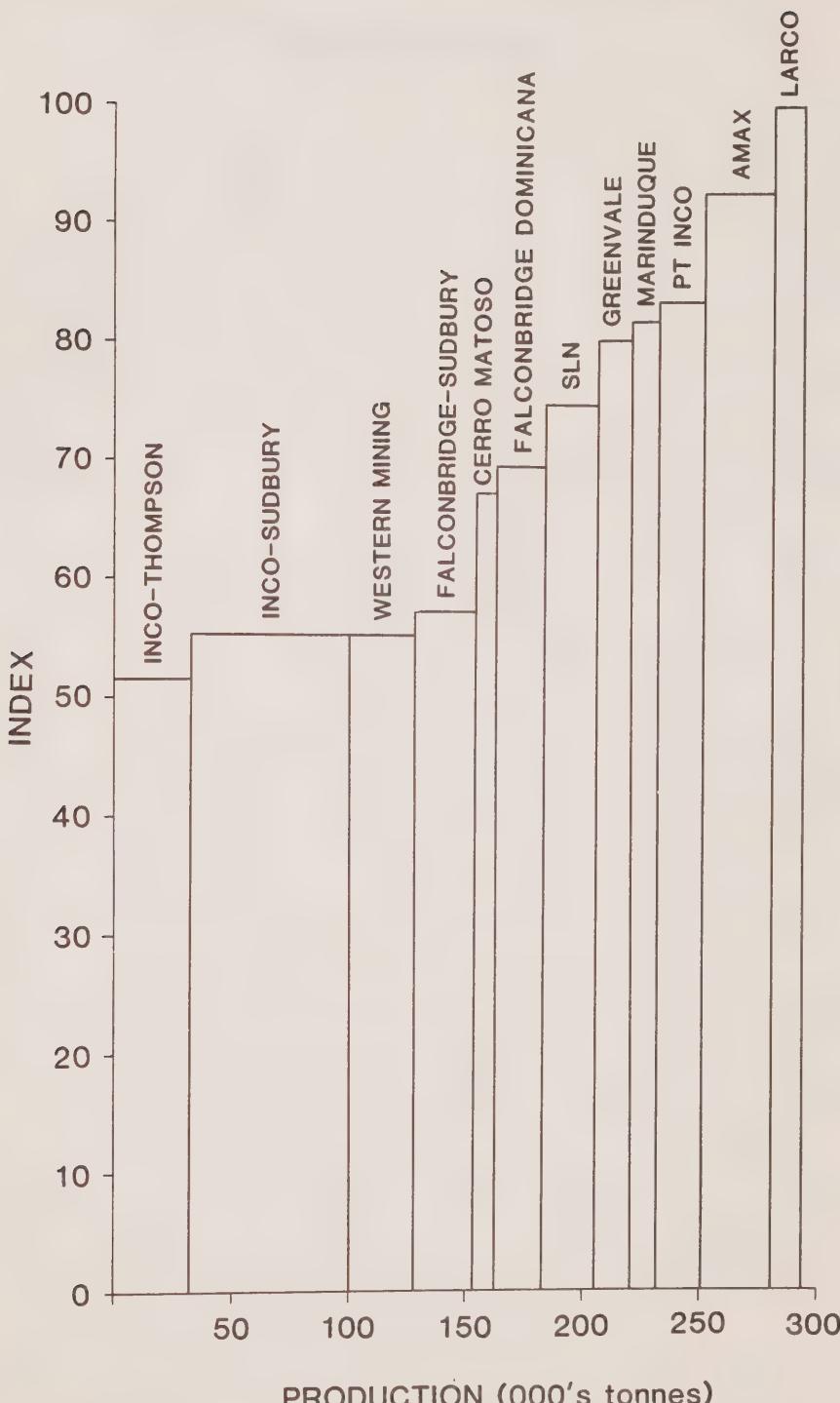
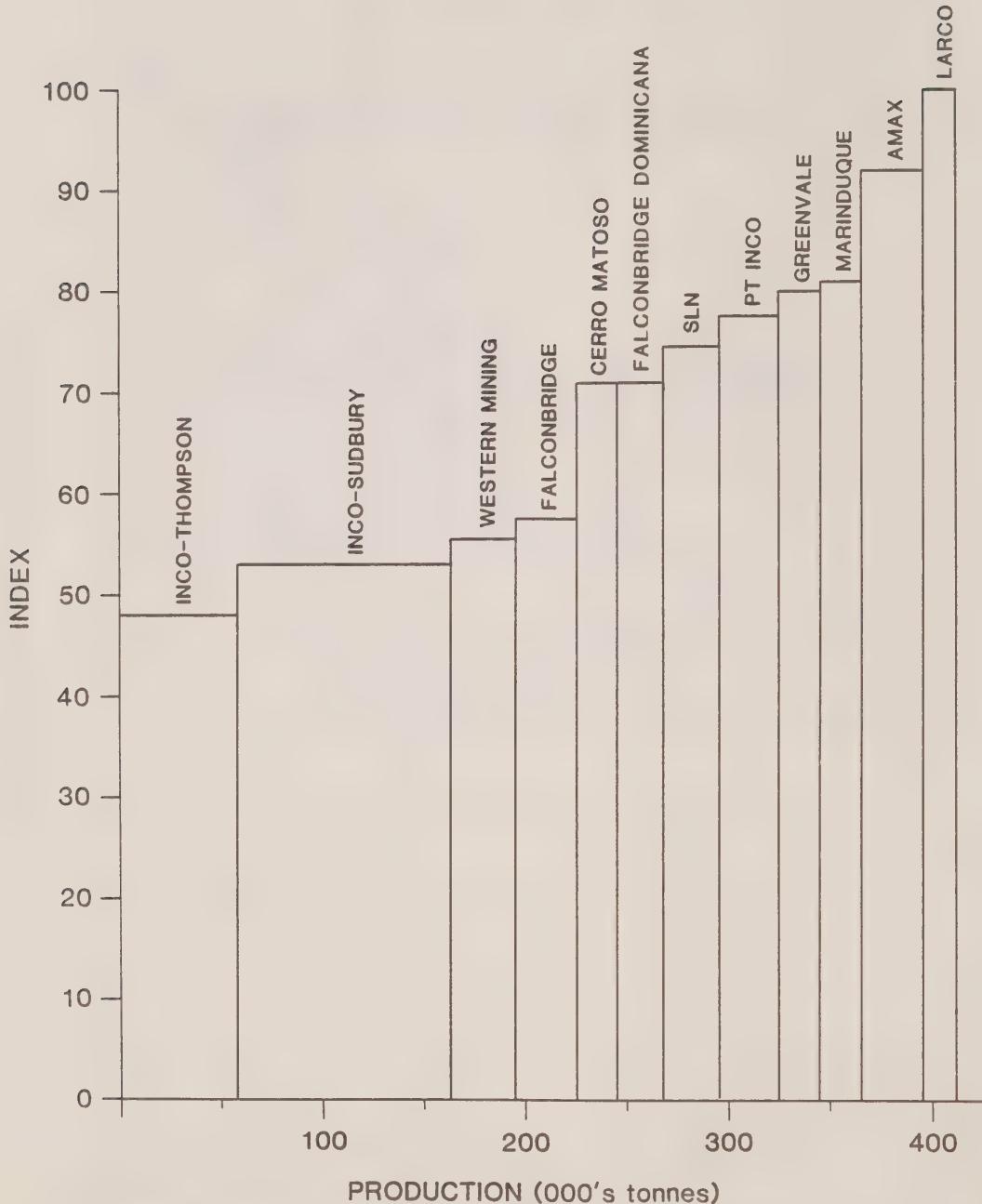
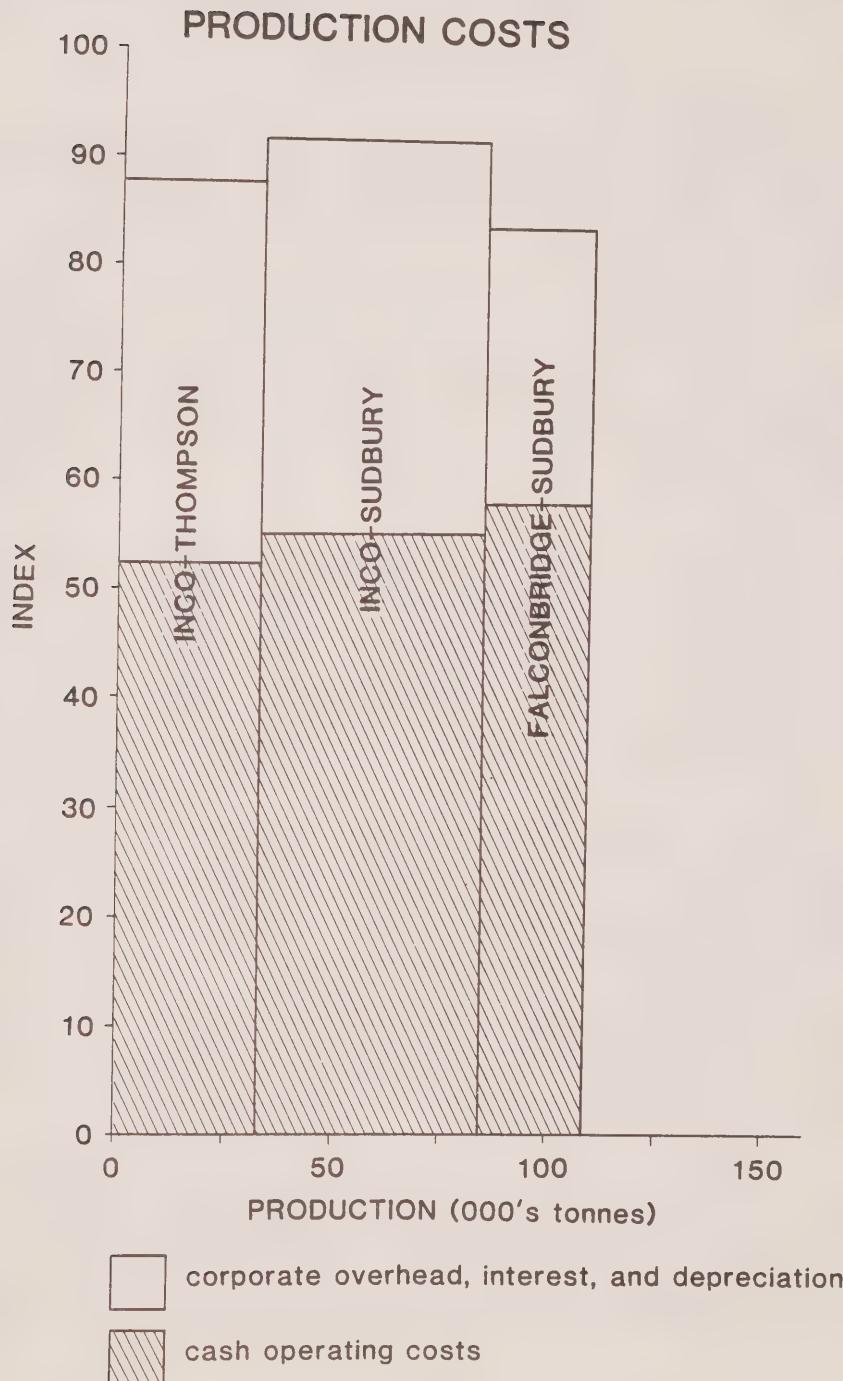


FIGURE 2.7
1990 OPERATING COSTS *



* No allowance has been made for smelter modernization and/or sulphur fixation programs

FIGURE 2.8



CHAPTER III

COPPER MARKET OVERVIEW

HISTORICAL PERSPECTIVE

Despite some differences, the world copper market has evolved in much the same manner as nickel in the postwar period. In the "golden" years, world copper consumption grew at an average annual rate of 4.4 per cent per annum (see Figure 3.1). Copper production around the world increased to meet demand and copper prices increased significantly in real terms, particularly from the mid-60s onward (see Figures 3.2 and 3.3).

Following the first oil shock, copper consumption, like that of nickel, fell abruptly. Notwithstanding strong growth in demand by LDC's, the cumulative impact of slower world economic growth, maturing industrial economies, downsizing for energy conservation, the substitution of other metals and materials for copper, and technological developments resulted in a rate of growth of world copper consumption of only 1.5 per cent per annum in the post-1973 period.

As with nickel, new copper mine production capacity was brought on-stream in the 1970s, despite faltering growth in world consumption. Copper markets have been and continue to be plagued by serious oversupply problems, which have put downward pressure on copper prices. Except for brief periods, copper prices have fallen steadily in real terms since the mid-1970s (see Figure 3.3). In 1983, average annual copper prices dropped to 64.2¢ U.S., the lowest level in real terms since World War II. Indeed, the 1983 copper price, in real terms, is only about one third of the average price level realized in 1974!

The 1980-82 recession saw a significant number of mine closures around the world. North American producers, which are relatively high cost, have borne the major burden of production cutbacks. Nevertheless, the copper market continues to be burdened by a surplus of copper metal and poor consumption growth prospects. A number of relatively high cost operations that have been hanging on in anticipation of price increases are becoming more and more vulnerable. Their situation is made worse by the very high proportion of world copper production which for a variety of reasons is not fully responsive to market forces. Unlike Canada's nickel producers, which are better situated to weather depressed market conditions, the problem faced by some North American copper producers is, in many cases, one of outright survival.

At the same time that markets for refined metal are plagued by oversupply, there is an international shortage of copper in concentrates. The large number of mine closures, the need for custom smelters to operate at high levels of capacity utilization to achieve economies of scale, and recent smelter openings and major expansions have all contributed to this situation. Treatment charges offered by smelters to copper mines on the

spot market have fallen to an all time low. This has placed a considerable burden on Canadian custom smelters, which do not benefit from a large protected domestic market like the Japanese and other custom smelters elsewhere in the world.

Major Characteristics of the World Copper Market

Industrialized countries, notably the United States, Japan and the EEC, account for almost 85 per cent of total world consumption. Developing countries are growing in importance as copper consumers. In particular, newly industrialized countries in Asia and Latin America have shown strong growth in recent years.

The United States has been a modest net importer (mostly of refined copper), and Japan and western Europe import most of their requirements. Japan relies largely on concentrate imports. Western European countries import a majority of their needs in refined form, but they are also significant buyers of blister and concentrates. Scrap is also a very important source of copper in the industrialized world. Currently, about 40 per cent of total copper metal supply is contributed by re-refined or direct-use scrap.

Unlike nickel, trade in copper concentrates is relatively important. Leading concentrate exporters and their rank in 1982 include the Philippines, Canada, Chile, United States (since 1980), Papua New Guinea (PNG) and Mexico. Of these countries, all but PNG have significant domestic smelter production. The Philippines completed construction of a major new smelter/refinery in 1983, and has become a less important source of copper concentrates. Japan and West Germany are the leading importers of concentrate, followed by South Korea, Brazil, Taiwan, Spain and a number of smaller importers. The United States was also a significant importer as well as an exporter in 1982.

At present, about 55 per cent of world copper mine production is found in developing countries. Prior to 1960, the copper industries in these countries were controlled by private companies. However, a wave of expropriations and takeovers by governments in many developing countries in the 1960s and 1970s, combined with subsequent expansion by state enterprises, has resulted in significant government control over world copper production. At present, it is estimated that over 40 per cent of western world primary copper production is owned or controlled by governments, and is consequently subject to production decisions based in part on employment, balance of payments and other considerations not directly related to copper market conditions. Many privately owned mines may also be required to operate at production levels set by government policies rather than reacting primarily to market circumstances. Of the major copper producing nations, most mines in Chile, Zambia and Zaire and some in Mexico, Peru and a few other countries, are owned or controlled by governments.

It should be noted that a number of important copper producing countries belong to the Intergovernmental Council of Copper Exporting Countries (CIPEC). Members are Chile, Peru, Indonesia, Zambia and Zaire,

and associate members are Australia, Papua New Guinea and Yugoslavia. While this organization may have aspired to achieving greater stability in copper prices, the evidence suggests that it has had relatively little impact.

The Canadian Copper Industry

Canada has long been one of the world's major copper producers. Currently, we rank fourth in the world after Chile, U.S.S.R. and the United States in terms of mine production. Canada's share of world copper production peaked at 11 per cent in 1973, declined to 7.4 per cent in 1982 and recovered slightly to 7.6 per cent in 1983.

Canada has been a highly competitive copper producer in world markets. Until the late 1960s, Canadian production came largely from relatively high-grade underground operations. With the development of low cost, open-pit mining methods using increasingly larger scale equipment and very large scale concentrators, it became feasible to mine open-pit copper deposits having very low grades. The new interest in low-grade, porphyry-type deposits in Canada led to the rapid discovery of over 50 such copper, copper-molybdenum and molybdenum deposits in Canada, mostly during the 1960s. Twelve of these were brought into production between 1962 and 1982, leading to a major increase in Canada's copper mine output during the 1960s and the first half of the 1970s. Further mine developments since that time have helped to maintain mining capacity. Canadian copper mine production peaked at 824 000 t in 1973 but has since fallen to 625 000 t in 1983. Mines representing about 160 000 to 170 000 tonnes per annum of capacity are now closed because of low prices for copper or other metals.

Canada's copper processing industry is also quite large. Smelters are located at Flin Flon, Manitoba; Sudbury, Ontario (two); Timmins, Ontario; Noranda and Gaspé, Quebec (a seventh smelter in British Columbia was permanently closed in 1982). Their combined capacity of copper production is approximately 650 000 tpy. These smelters were initially built to serve major captive mines. However, the large Noranda smelter and the Gaspé smelter are now primarily custom smelters which process concentrate from mines not only in Ontario and Quebec, but also from as far away as British Columbia and other countries. HBMS's Flin Flon smelter also relies on custom concentrates for about 50 per cent of its feed requirements. Smelted copper and some scrap is refined at three electrolytic refineries, located in the Sudbury area, Timmins and Montreal East, with the latter refinery serving the Flin Flon, Noranda and Gaspé smelters. One of the Sudbury area smelters exports nickel-copper matte for refining in Norway. Copper refining capacity in Canada is about 675 000 tpy.

About 40 per cent of Canadian copper mine production is exported in concentrate form. This share has roughly doubled since 1970 due to the development of new mines in British Columbia. Canada's major markets for concentrate are Japan and western Europe with growing markets in southeast Asia. The United States and western Europe are Canada's main export markets for refined metal. In 1980, Canada ranked second in world copper concentrate trade and third in refined metal trade.

COST COMPETITIVENESS OF MAJOR WORLD COPPER PRODUCERS

As Canada exports the majority of its copper production and levies no import tariffs on copper up to the refined stage, Canadian copper producers must remain cost competitive with producers elsewhere.

Competitive Position of Canadian Copper Mines

During the 1970s, world copper production costs in real terms had on average tended to remain fairly constant. For example, Frame* shows that from 1971 to 1981, break-even cash costs of all but the highest cost 15 per cent of mines, net of byproducts, were consistently less than \$.90 to \$1.00 (1982 US dollars) a pound. Average production costs over the same period (after byproduct credits, including interest but excluding depreciation and amortization) were not much more than 70 cents a pound (1982 US dollars), and dropped to as low as 60 cents (1982 dollars) in 1979-1980, when byproduct prices were high. Lowering of average costs has been particularly prevalent since 1981 because producers have implemented vigorous cost-cutting programs in the face of severely depressed prices.

In Canada, copper mine production costs net of byproduct credits on average stayed fairly close to the world average through the mid- to late-1970s, but the relative position of our mines improved significantly in 1980 and 1981, due to price escalation in precious metal and molybdenum byproducts, and favourable energy costs. Since then, our competitive position has deteriorated dramatically as a result of such factors as the strong Canadian dollar (relative to most competitors outside the United States, see Table 2.1), weaker byproduct metal prices, rising energy and labour rates, and in some cases, reduced operating rates or temporary closures. Most producers have implemented severe cost cutting measures but these have not been sufficient to offset other cost disadvantages in all cases.

The marked deterioration in the competitive position of Canadian copper mines since 1981 can be seen clearly in Table 3.2. Whereas 63 per cent and 79 per cent of Canadian copper production was in the first two and first three quartiles, respectively, in 1981, these shares fell to 44 per cent and 47 per cent, respectively, in 1983. Fully half of Canada's production was in the fourth quartile in 1983, compared to only 23 per cent in 1981. The pattern of Canadian mining production costs is reason for serious concern, especially because current world prices are not even sufficient to cover costs, excluding depreciation and amortization, for many producers in the second cost quartile.

The cost position of Canada compared with its major competitors in world supply is provided in Table 3.3. Production costs for most mines in Chile, Mexico and southern Africa fall into the first or lowest cost

* Sir Alistair Frame (Rio Tinto Zinc), "The Copper Industry in Crisis; Prices and Supply-Demand Balance", Copper 83 Conference, London, England, November 1983.

quartile. Papua New Guinea and most mines in Peru fall into the second quartile, those in Australia, Zaire and the Philippines fall mainly into the third quartile, and those in Zambia are split between the third and lower fourth quartile. Only about a quarter of U.S. capacity falls into the third quartile and all but 10 per cent of the remainder falls into the fourth quartile. Some hundreds of thousands of tonnes of additional capacity at mines that are closed is not included in the 1983 cost ranking. Costs at such mines would be comparable to some of the higher cost producers in the fourth quartile.

The cost position of Zaire as presented in Table 3.3 is somewhat misleading. Zairean copper mines, all operated by the government company La Generale Des Carrières et Des Mines du Zaire (Gecamines), appear to have relatively high operating costs. However, as they are among the country's few sources of government revenue, they are subject to high import and export duties and other taxes and expenses. In fact, Zaire is one of the world's lowest cost copper producers. Zairean copper production would not be deliberately cut, even if copper prices were to decline substantially from already low levels. Gecamines has, in fact, the potential to expand its production capacity considerably if it had the financial capacity to do so.

Country Comparisons

Both lower cost and higher cost producers are of interest in assessing Canada's current and future competitive position. The principal advantages of Chile and Peru, aside from low labour costs, are relatively high copper grades (typically 1 to 2 per cent compared with 0.5 per cent or less for Canadian open-pit copper mines) and large-scale open-pit mining. Byproduct credits are broadly comparable with those of Canadian porphyry-type copper deposits. Devaluations of national currencies and high capacity utilization have also helped to maintain their cost advantage.

Copper mines in Zaire also have high grades, averaging about 3.9 per cent in open-pit mines and 4.6 per cent in underground mines, which help to compensate for high transport costs. Labour costs are low and the Zairean cost advantage has been assisted by currency devaluations.

In countries typified by multi-metal deposits such as Australia, Papua New Guinea, South Africa and Mexico (in part), byproduct and coproduct values can be important factors in mining viability. Two-thirds of Australian copper production comes from the Mount Isa copper and zinc-lead-silver complex. Although the copper is produced from a separate orebody with only minimal byproduct revenue, copper production costs are lowered by the overall advantages of scale of the entire mining operation. The Bougainville mine in Papua New Guinea is a large open-pit copper mine currently yielding ore just under 0.5 per cent copper. However, byproduct gold and silver values together yield a "copper equivalent" grade of just over 1 per cent copper. Palabora, which accounts for three-fifths of South African copper production, is a large open-pit mine with large byproduct and coproduct revenues. In addition to having higher copper-equivalent grades, mines in some of these countries also enjoy the benefit of low-cost labour.

U.S. mining production costs for copper vary widely. Some operations at which copper is leached from dumps yield low-cost copper. However, production volumes from such operations are for the most part quite small. Copper mines currently operating in the United States yield only about two thirds of the recent annual U.S. mine copper output of about 1 500 000 tonnes. The remaining third is presently closed because of the combined effects of high costs and low copper prices. Given the relatively high production costs of many existing operating mines, it would appear that further U.S. production cutbacks are likely, unless there is some form of government intervention. For example, there is a possibility that restrictions could be imposed on copper imports into the United States as a result of the petition filed by U.S. copper producers in January 1984 under Section 201 of the International Trade Act.

In recent years, the Zambian copper producer, Zambia Consolidated Copper Mines, Ltd., has found itself in an increasingly difficult financial position because of depressed metal prices, low ore grades, poor milling recoveries, financial restrictions and excessive government taxation, including an 8 per cent export tax on copper. At the same time, production capability at some of the company's mines is declining and available ore reserves are diminishing. Geological potential for the discovery of new ore in Zambia is limited. Consequently, Zambian copper production will probably decline by the end of this century. One of the major problems of Zambia Consolidated Copper is a lack of capital that is essential if the company is to break out of the destructive cycle in which it finds itself. To be able to compete, large investments in technology, mine exploration and development, and new and replacement equipment are essential, but under present conditions the company has been unable to obtain the funds it requires. The World Bank and some other regional development banks are currently considering a major loan to Zambia to revitalize the copper industry.

The orebodies at most Philippine copper mines are very low grade, many of them even lower grade than the Canadian porphyry-type deposits. Low wage rates do not fully compensate for low grades. Consequently some mines have already closed (e.g., the Sipalay mine of Marinduque Mining and Industrial Corporation) and others are likely to follow as a result of financial difficulties brought about by low copper prices.

In summary, with current copper prices well below average world costs, relatively few world copper mines are profitable. Although some Canadian mines have relatively low costs, Canada as a whole has recently become a relatively high-cost copper producer by world standards, and few Canadian copper mines are profitable. Those that are profitable are fortunate to enjoy the benefits of large coproduct and byproduct revenue. Some of the highest cost Canadian copper mines continue to produce, in anticipation of improved market conditions and because costs of closing and reopening a mine would be considerable. Some producers have been consuming their available capital by continuing to operate, and other operations have survived only by mining material that is higher than average ore reserve grade. Such measures cannot be sustained over the long term. Consequently, a number of Canadian copper mines can be expected to close unless there is a notable improvement in copper market conditions.

Competitive Position of Custom Smelters*

Table 3.4 provides an index of direct operating costs for some of the major custom smelters in the world. Smelters from four countries are included: Canada, Japan, Philippines and the United States. Cost comparisons to the Japanese smelters are most relevant as they control about two thirds of the copper concentrate market and are price leaders in establishing treatment charges. The index is based on the weighted average direct operating costs per tonne of copper for all smelters listed in this table, after acid credits. Interest, depreciation, amortization and freight costs are excluded.

The new PASAR smelter in the Philippines has the lowest operating costs of those custom smelters listed in Table 3.4. The Horne smelter composite, i.e., reactor-reverb, falls into the middle range of costs and is quite competitive with the direct operating costs of the Japanese smelters. The Noranda Gaspé and the HBMS Flin Flon operation have slightly higher costs, but both are competitive.

In comparison to our major competitors, Canadian smelters generally have a significant advantage in energy costs and in some cases higher metal recoveries. Canada's major disadvantages appear to be in labour costs and materials and supplies, including materials handling. In comparison to the Gaspé and Flin Flon smelters, many of the foreign smelters as well as the Noranda Horne facility employ more modern technology, which confers an advantage to these operations.

Although direct operating costs are important, this factor tends to hold secondary importance in determining competitive position and ability to compete for copper concentrates in world markets. This is because many custom smelters outside North America enjoy the benefit of selling into a large protected domestic market or other forms of government intervention which support their operations.

The Japanese situation stands as a good example, particularly as it has served as a model for other countries. Japan maintains a relatively high tariff on copper cathode imports (about 8.5 per cent). Because similar tariff schedules are not applied to imports of ore and concentrates, Japanese producers can sell refined copper in their domestic market at prices 7 to 8 per cent above London Metal Exchange (LME) prices. Over the last several years, the Japanese Producer Price (JPP) has exceeded the LME by an average of 4 to 8¢/lb U.S. This provides Japanese smelters tremendous scope to outbid European and North American smelters for copper concentrates. In Canada, the Japanese system of tariffs has conferred a benefit to copper mines in British Columbia. However, at the same time, it has made it more difficult for Canadian custom smelters to compete for these concentrates.

* The analysis in this section of the report draws heavily on various reports prepared by Brian E. Felske and Associates.

Japanese smelters also benefit from being located on tidewater, close to final markets and having access to a large market for sulphuric acid. Rather than being a negligible byproduct as it is for most North American smelters, sulphuric acid sales provide Japanese smelters a large source of revenue. In 1981, sulphuric acid sales contributed an average revenue of 5.3¢/lb U.S. of copper cathode produced.

Taiwan, South Korea and Brazil appear to be following the Japanese model. In Taiwan and South Korea the tariff on imported refined copper exceeds 20 per cent. Similarly, Brazil, through a combination of tariffs and import restrictions, provides substantial effective protection to domestic copper operations.

These supportive policies by major consuming interests have resulted in a continuing strong demand for copper concentrates. The recent closure of many mines around the world due to low copper prices has on the other hand resulted in a decline in concentrate supply. This has been reflected in increasingly low treatment and refining charges (TC/RC) being offered to sellers of copper concentrate, as smelters desperately attempt to obtain concentrates required to maximize throughput and minimize operating costs. By late 1983, spot TC/RCs were reported to have fallen to as low as 8¢/lb U.S., although many mines were still paying 20¢ or more under long-term contracts. The latter more closely approximates the treatment charges required to yield an operating profit at most custom smelter operations around the world.

As mentioned earlier, all of Canada's custom smelters were initially built to serve major local mines in fairly remote inland areas of Canada. The exception, in terms of location, is Noranda's Gaspé smelter which is close to tidewater. Because of the relatively low metal-to-concentrate ratio, the proximity of the smelter to the original mines resulted in significant transportation cost savings. This enhanced the competitive position of Canadian mines and smelters and, in some measure, shielded them from the vagaries of the international copper concentrate market. Unfortunately, the major orebodies which originally supported these operations are nearing depletion or have been closed. Moreover, feed from other local captive and non-captive sources appears to be on the decline. Consequently, Canadian custom smelters will be required to look increasingly towards non-local (British Columbia) and offshore sources of concentrate to satisfy feed requirements. This development will result in all three establishments having to bear additional transportation costs in order to compete with Japanese and other foreign smelters for scarce concentrate.

This transportation cost disadvantage is substantial. For example, it is estimated that the Horne and Flin Flon operations would have to bear a transportation cost penalty of 4-9¢/lb U.S. of copper in relation to Japanese competition in competing for copper concentrate mined in the interior of British Columbia. At current prices of 65¢/lb U.S. for metal and low treatment charges, it appears that neither HBMS nor Noranda would have much economic incentive to purchase British Columbia concentrates. However, in recent years the Horne smelter has relied heavily on British Columbia as a source of feed. This may be due to higher metal recoveries

(including byproducts) at the Horne smelter compared to Japanese smelters. Alternatively, the incremental feedstock may permit substantial economies of scale to be realized, thus effectively lowering its cost of purchase. Nonetheless, there is some question regarding the extent to which the Horne smelter can continue to process British Columbia concentrate profitably.

In the case of the Gaspé smelter, Noranda has been able to obtain limited supplies of Chilean copper concentrates. Gaspé is competitive in bidding for South American concentrates, at least with respect to inbound freight. However, it faces high metal to market costs, since the domestic market cannot absorb production. To illustrate, total freight costs included in a pound of Chilean copper smelted and refined by Noranda at the Gaspé smelter and CCR refinery, and then delivered to a customer in Montreal amount to about 5-6¢/lb U.S. If the metal were shipped to a European port or the northeastern United States, the transportation costs that would be incurred could approach 7-8¢/lb U.S. and 8-9¢/lb U.S. respectively. If the same concentrates were treated at the Horne rather than the Gaspé smelter, approximately 4 cents a pound in additional freight costs would be incurred. Additional supplies of Chilean copper concentrates could be purchased, however high metal-to-market costs could be prohibitive for either of the Noranda smelters to treat them profitably.

In 1984, Canadian custom smelters find themselves in a highly vulnerable position. The fact that they can continue to operate at such depressed copper prices is an indication of their inherent strength. However, reservations remain about the future of these operations. Unlike the new PASAR smelter, which through government intervention is guaranteed feed from local sources at treatment charges which cover operating costs and a large portion of its financial charges, Canadian smelters must compete in an increasingly difficult and complex market without the benefit of a large protected domestic market and/or direct government subsidy programs.

Looking Forward

The shortage of concentrate on the international market is expected to last until the end of the decade. The only certain new contributors to international deliveries will be Tintaya in Peru, Batong Buhay and Hinobasaan in the Philippines, Mantos Blancos and Andina in Chile and Ok Tedi in Papua New Guinea. It is possible that the giant Olympic Dam project in Australia and the La Escondida project in Chile will be developed but their effect on concentrate markets will not be felt until the 1990s. In 1983, the net result of production losses and fewer new producers was a reduction in available concentrates on the international market by 200 000 tonnes from the 1.5 million tonnes traded in 1982. At present, there is a severe shortage of concentrate, approaching some 200 000-400 000 tonnes. For the balance of the decade, a shortage of between 100 000 and 220 000 tonnes per year is forecast. This shortage will be alleviated only if the large new mines in Chile and Australia are brought into production or, alternatively, if there are further temporary or permanent smelter production cutbacks or closures in the United States, Europe, Japan or Canada.

The total smelting and refining charge in long-term contracts up until the recent concentrate shortage averaged 19-21¢/lb U.S. Today, reasonably long-term arrangements are being made at 11-14¢/lb U.S. Since a number of mines had previously entered into long-term contracts, in some cases 10 years, the revenue currently received by Japanese smelters is an average of these charges. The projected shortage of concentrates will continue to keep treatment charges at low levels for at least the balance of this decade.

Direct copper smelting costs in the western world currently range from \$U.S. 140 to over \$U.S. 500 per tonne of anode with Canadian plants operating in the middle of that range. While the operating efficiencies of most of our smelters are comparatively good, freight costs to haul concentrates to the remote smelter locations and to haul refined metal to market continue to place them at a disadvantage. The most important point, however, is that operating efficiency cannot overcome the difference between current Japanese smelter terms and those currently required in North America.

The balance of the 1980s could prove to be a very difficult period for Canada's custom smelters. In the case of the Flin Flon operation, it has the advantage of being a moderate cost producer. However, Sherritt Gordon Mines Limited's recently announced plans to close its Ruttan mine temporarily in June of this year and its Fox mine permanently in two years time have made HBMS's concentrate supply picture more uncertain. In addition, because of cutbacks in exploration in recent years, HBMS' own reserve position has shown some deterioration. The company is confident that there will be adequate feed to maintain operation. However, it is imperative that HBMS undertake aggressive exploration and mine development programs to rebuild its reserve position in northern Manitoba and reduce its reliance on custom feed. HBMS also has the advantage of being an important producer of zinc and precious metals. Current favourable zinc prices and valuable precious metal credits are primarily responsible for the company generating positive cash flow at this point in time.

The Noranda Horne smelter is also expected to face an increasingly uncertain concentrate supply picture. Many of the smaller mines and a few of the larger ones that produce concentrates for smelting at the Horne will be exhausted (or forced to close because of low metal prices) over the next 5 to 15 years. A major source of concentrates could also be lost if Kidd Creek Mines Limited expands its copper smelter at Timmins, Ontario. Unfortunately, major new mine developments are not expected to be brought on-stream to replace depleted mines. The rate of discovery of new copper deposits in Quebec and Ontario has dropped off and since copper prices are forecast to remain relatively low for some years, only a small proportion of new discoveries is likely to be economically viable. Because of its unfavourable location, the smelter's ability to process increasingly large quantities of concentrate from non-local sources at a profit is questionable. Similarly, adequate alternative sources of material in the form of scrap also may not be available. The major crunch for the Noranda Horne smelter could occur sometime in the late 1980s or early 1990s. It is quite possible that at that time the smelter may be forced to limit its production until copper concentrate markets improve.

The Gaspé smelter also faces difficult circumstances. Although a major orebody has been discovered underneath the town of Murdochville, Noranda has estimated that 90-cent (U.S. 1982) copper is needed to justify this new development and to bring the entire Gaspé mining operation back into production. This smelter should continue to obtain small quantities of concentrates from New Brunswick mines but its viability will be determined by Noranda's ability to purchase very large quantities of offshore feed at favourable terms. Gaspé is located relatively close to tidewater and therefore does not suffer as severe a transportation cost disadvantage as Canada's other custom smelters. However, its future is very much clouded. The Gaspé smelter could operate at substantially less than full capacity rates of production for protracted periods of time over the next several years.

OUTLOOK*

Demand

The outlook for world copper demand is not overly optimistic. The further substitution of aluminum for copper wire and cable, and plastic for copper pipe, etc. will likely continue but at a slower pace. Fortunately, the downsizing of vehicles for energy conservation has almost been completed. However, the main challenge could come in the area of communication wire, where optic fibres could be a major threat in a traditional copper end-use market. While some new uses of copper are likely to be developed over the forecast period, they are expected to have only a limited impact on overall consumption trends. The slower world economic growth and the maturing industrial economies will continue to retard demand overall. The major bright spot in the market is the expected above world average growth in copper consumption in many developing and newly industrialized countries. Copper consumption in the non-communist world is expected to grow by only 1.2 per cent per year from 1981 to 1990 and 1.6 per cent from 1990 to 2000 (see Table 3.5).

Supply

Non-communist world copper production capacity is expected to grow by an average of 1.4 per cent per year from 1982 to 1995 (see Table 3.6) compared with 2.2 per cent over the 1970-1981 period. Australia is expected to show the largest growth in capacity, 4.0 per cent per year, followed by Latin America with 2.6 per cent and Asia with 2.1 per cent. African mine capacity is predicted to decrease by 0.1 per cent per year during the 1982-1995 period.

For the United States, no growth in capacity is expected from present low levels. Until the copper price recovers (i.e. late 1980s) effective U.S. production capacity may even decline temporarily from current highly depressed levels due to further mine closures.

* What follows is EMR's forecast of world copper market. As with all forecasts there is uncertainty in trying to predict the future.

Overall, it is quite possible that world copper mine capacity may increase more rapidly than consumption because of unrealistic expectations of consumption growth and favourable TC/RC's. Large expansions are expected mostly in Australia and Chile, where low-cost reserves are known and are likely to be developed.

Canadian Production

Effective Canadian copper mine capacity (maximum output attainable at existing or forecast copper prices), which declined by 14 per cent between 1981 and 1982, is expected to increase by only 0.3 per cent per year during the 1981-2000 period (Table 3.7). This projection represents a sharp decline from the 1970-1981 annual average growth in mine production of 1.5 per cent. Except possibly for brief periods (1 to 2 years) Canadian copper production is not expected to equal the level attained in 1981 (691 000 tonnes) for at least the remainder of this century. Major reductions in production capacity are expected in central Canada. British Columbia is expected to become the predominant copper mining region in Canada by the end of this century.

As mentioned earlier, world copper concentrate markets are expected to remain tight for the balance of this decade. This is expected to create difficult operating circumstances for Canada's custom smelters. Other than the possibility of some expansion of the Kidd Creek copper smelting and refining operation, the prospects for expansion in smelting capacity appear to be quite limited.

Price

Large producers of copper have undertaken or are in the process of undertaking major cost cutting and productivity improvement programs. This, in combination with low cost new mines which can and will be brought on-stream in the future, suggests that some of the major copper producers around the world will be able to generate normal profits at prices considerably lower than historic levels. Copper prices will also continue to be under pressure, because of the large proportion of world production which is controlled by governments or which is byproduct production and therefore less responsive to market forces. World copper markets will continue to be plagued by severe surpluses in potential supply, which will limit increases in the price of copper.

The LME price for copper, in 1982 U.S. dollars, is expected to average 70¢ per pound in 1984, gradually rising to 80¢ by 1988 and to 85¢ by 1989, where it will remain until well into the 1990s. This projected long-term price of copper compares to the average copper price of \$1.70 which prevailed in the early 1970s (see Table 3.8).

SUMMARY COMMENT

The outlook for the Canadian, and indeed for the North American, copper industry is not favourable. Some mining operations face permanent closure or shutdowns for protracted periods of time. Canada's custom copper smelters, in particular, face very difficult market circumstances. These operations must work to reduce their reliance on non-local sources of feed and to improve productivity to offset locational and other disadvantages under which they are likely to operate now and in the future.

TABLE 3.1

Currency Devaluations Relative to the U.S. dollar, 1983 versus 1982

	<u>Per cent Devaluation</u>	<u>1982 copper Production (000 t)</u>
United States	0	1 140
Chile	-35	1 240
Canada	+0.1	606
Zambia	-25	530
Zaire	-56	503
Peru	-57	356
Philippines	-23	293
Australia	-11	247
Mexico	-54	239
South Africa	-3	207
Papua New Guinea	-12	170
Yugoslavia	-46	119
Indonesia	-27	75
Spain	-24	58

Source: Mineral Policy Sector, EMR.

TABLE 3.2

Cost Competitive Position of Canada's Copper Mine Producers*

Quartile of World Cash Costs	1981		1983	
	Cdn Prod'n (million lb)	Per cent of Total	Cdn Prod'n (million lb)	Per cent of Total
1st (lowest cost)	585	45	85	8
2nd	230	18	390	36
3rd	180	14	27	3
4th (highest cost)	305	23	570	53
Total	1 300	100	1 075	100

Source: Brook Hunt and Associates Ltd. (1983), includes estimates and projections.

TABLE 3.3

Competitive Cost Ranking of Major Copper Mine Producers, 1983*

	Share of 1982 Mine Production (%)	Cost Index (W. World Av. = 100)
Chile	15	66
Papua New Guinea	2	89
Mexico	3	92
S. and S.W. Africa	3	95
Peru	4	95
Zaire	6	110
Australia	3	112
Zambia	6	115
CANADA	7	116
United States	14	116
Philippines	6	119
Others	14	—
Western World	100	100

Source: Brook Hunt and Associates Ltd. (1983).

* Includes all costs except depreciation, amortization and profit taxes. Where copper accounts for 65 per cent of total revenue or more, coproduct and byproduct metal values are treated as credits. Where copper accounts for less than 65 per cent of total revenues, common costs are allocated to each metal in proportion to revenue.

TABLE 3.4
Estimated Direct Operating Cost Indices for Selected Copper Smelters*

Company	Smelter	Location	Process	Direct Cost Index*	
				Annual Capacity Tonne Copper	(Custom Smelters Only)
Hudson Bay Mining & Smelting Co., Ltd.	Flin Flon	Flin Flon, Manitoba	Roaster-Reverb.	68 000	1.07
Noranda Mines Limited	Gaspé	Murdochville, Quebec	Roaster-Reverb.	75 000	1.05
Anahé Kyodo	Onahama	Onahama, Japan	Reverb.	230 000	1.04
Furukawa Co. Ltd.	Ashio	Ashio, Japan	Flash (Oxygen Enriched)	42 000	1.03
Mitsubishi Corporation	Naoshima	Naoshima, Japan	Reverb. and Mitsubishi Process	168 000	0.98
Noranda Mines Limited	Horne Smelter Composite**	Noranda, Quebec	Reactor & Reverb. (oxygen enriched)	220 000	0.97
Nippon Mining Co. Ltd.	Sagenosaki	Japan	Flash (Hot Air)	240 000	0.95
Philippine Associated Smelting and Refining Corporation	PASAR	Leyte, Philippines	Modified Outokumpu Flash	138 000	0.80

Source: Brian E. Felske and Associates Ltd. and Mineral Policy Sector, EMR.

* Based on weighted average direct operating costs per tonne of copper for custom smelters in this table, after acid credits. Excludes interest, depreciation and amortization costs. ** Estimate of combined operation of reactor and reverberatory furnaces.

TABLE 3.5
Refined Copper
Consumption - Most Probable Scenario

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
(thousand tonnes of copper)																				
Canada	242	152	190	240	241	241	242	243	244	244	244	244	246	246	247	247	248	249	250	251
United States	1890	1660	1790	1890	1890	1893	1895	1898	1900	1902	1905	1907	1910	1912	1914	1916	1918	1920	1922	1924
Central & South America	431	438	440	446	451	471	484	516	539	565	590	618	646	675	706	739	773	808	845	885
Japan	1254	1335	1250	1300	1316	1333	1351	1369	1387	1405	1424	1443	1461	1480	1500	1520	1540	1559	1580	1601
Other Asia	365	341	345	365	390	419	448	479	514	550	590	631	676	724	775	830	889	952	1019	1091
Australasia	138	126	133	138	140	143	145	148	150	152	155	157	159	163	167	170	173	175	179	
Africa	113	105	108	112	115	120	125	129	133	139	143	148	154	160	165	171	177	183	190	196
Six EEC countries	2161	2167	2240	2300	2311	2323	2346	2359	2371	2384	2395	2408	2421	2433	2445	2458	2470	2471	2483	
Rest of Western Europe	508	523	526	529	532	535	538	542	549	557	565	571	579	587	594	602	610	618	626	634
Total noncommunist world refined consumption	7102	6847	7022	7320	7478	7487	7563	7670	7775	7885	8000	8116	8240	8369	8500	8639	8785	8933	9079	9245
Less net imports from communist bloc (included in above)	54	53	(150)	40	30	20	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Consumption of refined copper from non-communist sources	7048	6794	7172*	7280	7356	7458	7553	7676	7775	7885	8000	8116	8240	8369	8500	8639	8785	8933	9079	9245
Less refined copper from secondary sources	1093	1095	1124	1170	1482	1196	1210	1227	1244	1262	1280	1299	1318	1339	1360	1382	1406	1429	1449	1479
Primary refined copper consumption for non-communist world	5955	5699	6048*	6110	6174	6262	6343	6449	6531	6623	6720	6817	6922	7030	7140	7257	7379	7504	7630	7766

Source: Mineral Policy Sector, EMR.

* Includes net exports to communist nations in 1983.

Note: copper scrap used directly in the production of brass and other copper alloys is not included.

TABLE 3.6

World Mine Production of Copper 1970-1982
thousand tonnes of copper
(percentage of world production in brackets)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
United States	1 560.9 (24.6)	1 380.9 (21.4)	1 510.3 (21.5)	1 550.5 (20.9)	1 448.8 (18.9)	1 280.0 (17.4)	1 461.8 (18.3)	1 364.4 (17.2)	1 357.6 (17.3)	1 443.6 (18.2)	1 181.1 (15.0)	1 538.2 (18.5)	1 135.0
U.S.S.R.*	925.0 (14.6)	990.0 (14.6)	1 030.0 (14.6)	1 060.0 (14.6)	1 060.0 (14.6)	1 100.0 (15.8)	1 100.0 (15.0)	1 100.0 (15.0)	1 100.0 (15.0)	1 130.0 (14.0)	1 140.0 (14.4)	1 140.0 (13.7)	n.a.
Chile	685.6 (10.8)	708.3 (11.4)	716.8 (10.2)	735.4 (9.9)	902.1 (10.2)	828.3 (11.8)	1 005.2 (11.3)	1 054.2 (12.6)	1 034.2 (13.3)	1 062.7 (13.2)	1 067.9 (13.4)	1 081.1 (13.0)	1 240.7
Canada	610.3 (9.6)	654.5 (10.2)	719.7 (10.2)	822.9 (11.1)	821.4 (10.7)	768.8 (10.5)	723.6 (9.1)	759.4 (9.6)	659.4 (8.4)	636.4 (8.0)	716.4 (9.1)	718.1 (8.6)	620.0
Zambia	684.1 (10.8)	651.4 (10.1)	717.7 (10.2)	706.6 (9.5)	698.0 (9.1)	676.9 (9.2)	708.9 (8.9)	656.0 (8.2)	643.0 (8.2)	588.3 (7.4)	595.8 (7.0)	587.4 (7.6)	529.7
Zaire	387.1 (6.1)	405.8 (6.2)	487.7 (6.6)	494.6 (6.4)	494.8 (6.4)	444.6 (6.7)	481.6 (6.1)	423.8 (5.6)	423.8 (5.4)	399.8 (5.0)	459.7 (5.8)	504.8 (6.1)	494.9
Peru	205.5 (3.2)	207.4 (3.2)	219.1 (3.1)	215.0 (2.9)	213.2 (2.4)	173.8 (2.8)	219.4 (2.8)	329.4 (2.8)	329.4 (2.8)	376.4 (4.8)	397.2 (5.0)	366.8 (4.7)	355.8
Poland	83.0 (1.3)	122.2 (1.9)	135.0 (1.9)	152.0 (1.9)	185.0 (2.0)	230.0 (2.4)	310.0 (3.0)	282.0 (3.0)	312.0 (3.0)	340.0 (3.5)	343.0 (4.3)	343.0 (3.7)	n.a.
Philippines	160.3 (2.5)	197.4 (3.1)	213.7 (3.0)	221.2 (3.4)	221.2 (2.9)	225.5 (3.1)	231.5 (2.9)	272.8 (3.1)	263.4 (3.4)	298.3 (3.4)	304.5 (4.4)	302.3 (3.7)	284.5
Mexico	61.0 (1.0)	63.2 (1.0)	78.7 (1.1)	80.5 (1.1)	82.7 (1.1)	78.2 (1.1)	89.0 (1.1)	89.7 (1.1)	87.2 (1.1)	107.1 (1.1)	175.4 (1.4)	230.2 (2.2)	230.0
Australia	157.8 (2.5)	177.3 (2.6)	185.3 (2.8)	220.3 (3.0)	251.3 (3.0)	218.9 (3.0)	214.3 (3.0)	221.6 (2.7)	222.1 (2.7)	237.6 (2.8)	243.5 (3.0)	225.0 (2.7)	246.0
South Africa	144.2 (2.3)	148.4 (2.3)	161.9 (2.3)	175.8 (2.4)	179.1 (2.4)	178.9 (2.4)	197.9 (2.5)	205.4 (2.6)	209.3 (2.7)	203.2 (2.7)	211.9 (2.7)	210.6 (2.7)	207.2
Papua New Guinea	-	-	124.0 (1.8)	182.8 (1.8)	184.1 (2.5)	172.5 (2.4)	170.5 (2.5)	182.3 (2.2)	198.6 (2.3)	170.8 (2.2)	146.8 (1.9)	165.4 (2.0)	170.0
Yugoslavia	90.8 (1.4)	94.4 (1.5)	103.1 (1.5)	111.8 (1.5)	112.1 (1.5)	114.9 (1.5)	114.9 (1.6)	103.3 (1.6)	116.2 (1.5)	123.3 (1.5)	111.4 (1.5)	116.8 (1.5)	122.0
Mongolia	-	-	-	-	-	-	-	-	4.0	21.7	44.0	71.8	n.a.
Indonesia	-	-	5.0 (.5)	37.9 (.5)	64.6 (.8)	63.5 (.9)	66.8 (.8)	57.1 (.7)	58.0 (.7)	60.2 (.7)	59.0 (.8)	62.6 (.8)	75.1
Bulgaria	37.9 (.6)	35.0 (.5)	38.0 (.5)	48.0 (.5)	50.0 (.6)	55.0 (.7)	54.0 (.7)	57.0 (.7)	58.0 (.7)	60.0 (.7)	62.0 (.8)	62.0 (.7)	n.a.
China*	120.0 (1.9)	130.0 (2.0)	135.0 (1.9)	140.0 (1.9)	150.0 (2.0)	160.0 (2.0)	162.0 (2.0)	170.0 (2.1)	175.0 (2.2)	175.0 (2.2)	177.0 (2.3)	182.0 (2.2)	n.a.
Other communist countries	38.2 (.6)	51.6 (.8)	62.4 (.9)	70.3 (.9)	70.1 (.9)	73.8 (1.0)	81.0 (1.0)	64.6 (.8)	64.6 (.8)	66.1 (.8)	66.1 (.8)	67.9 (.8)	n.a.
Other non-communist countries	393.8 (6.2)	422.9 (6.6)	445.8 (6.3)	480.2 (6.5)	463.8 (6.1)	455.8 (6.2)	496.3 (6.1)	482.2 (6.2)	444.3 (6.1)	418.9 (5.6)	396.5 (5.0)	437.4 (5.2)	530.7
WORLD TOTAL	6 344.6	6 441.7	7 038.8	7 444.9	7 656.4	7 349.9	7 973.1	7 965.8	7 854.2	7 926.7	7 864.2	8 333.4	n.a.

Source: Mineral Policy Sector, EMR.

* Includes some additional Asian production.

- Nil; n.a. Not available.

TABLE 3.7
Canadian Copper Mining Capacity

Year	British Columbia, Yukon, and NWT	Manitoba, Saskatchewan, Ontario, Quebec & Atlantic Provinces	Other new mines in all parts of Canada	Canada Total
(tonnes of copper in concentrates)				
1981	314 000	424 000	-	738 000
1982	279 000	341 000	-	645 000
1983	286 000	339 000	*	625 000
1984	295 000	323 000	*	618 000
1985	305 000	318 000	*	623 000
1986	305 000	313 000	*	618 000
1987	305 000	313 000	*	618 000
1988	305 000	313 000	2 500	621 000
1989	325 000	313 000	5 000	643 000
1990	345 000	308 000	5 000	658 000
1991	350 000	303 000	15 000	668 000
1992	350 000	293 000	15 000	658 000
1993	365 000	283 000	20 000	668 000
1994	370 000	274 000	35 000	679 000
1995	375 000	270 000	35 000	680 000
1996	385 000	265 000	35 000	685 000
1997	385 000	265 000	45 000	695 000
1998	385 000	260 000	50 000	695 000
1999	385 000	250 000	57 000	692 000
2000	385 000	245 000	58 000	688 000

Source: Mineral Policy Sector, EMR.

* Included in regional totals; - Nil.

Note: Approximately 95 to 99 per cent of copper in concentrates is recovered in smelting and refining.

TABLE 3.8

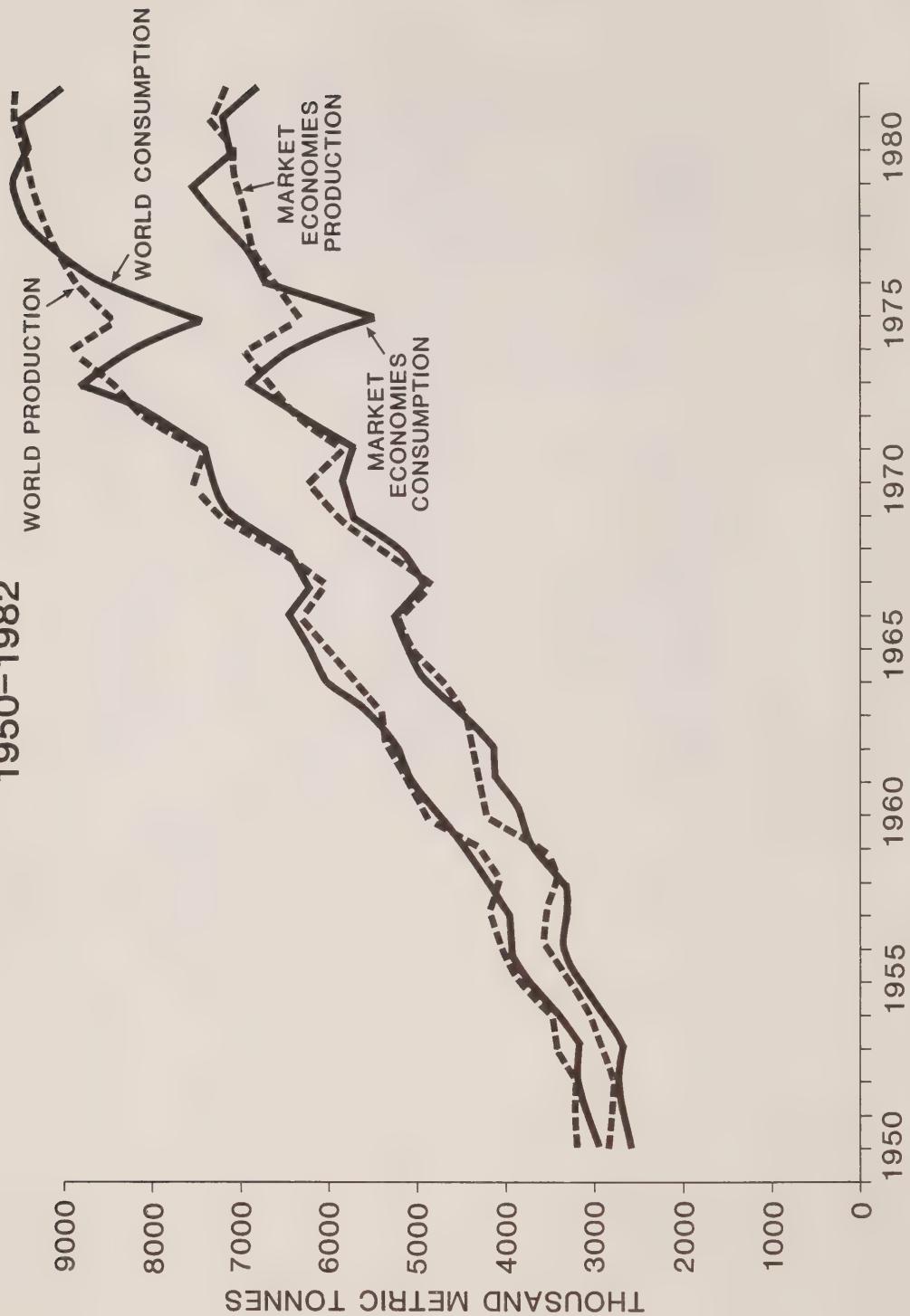
COPPER PRICE FORECAST
1982 \$U.S./lb

1984	.70
1985	.72
1986	.74
1987	.76
1988	.80
1989-2000	.85

Source: Mineral Policy Sector, EMR.

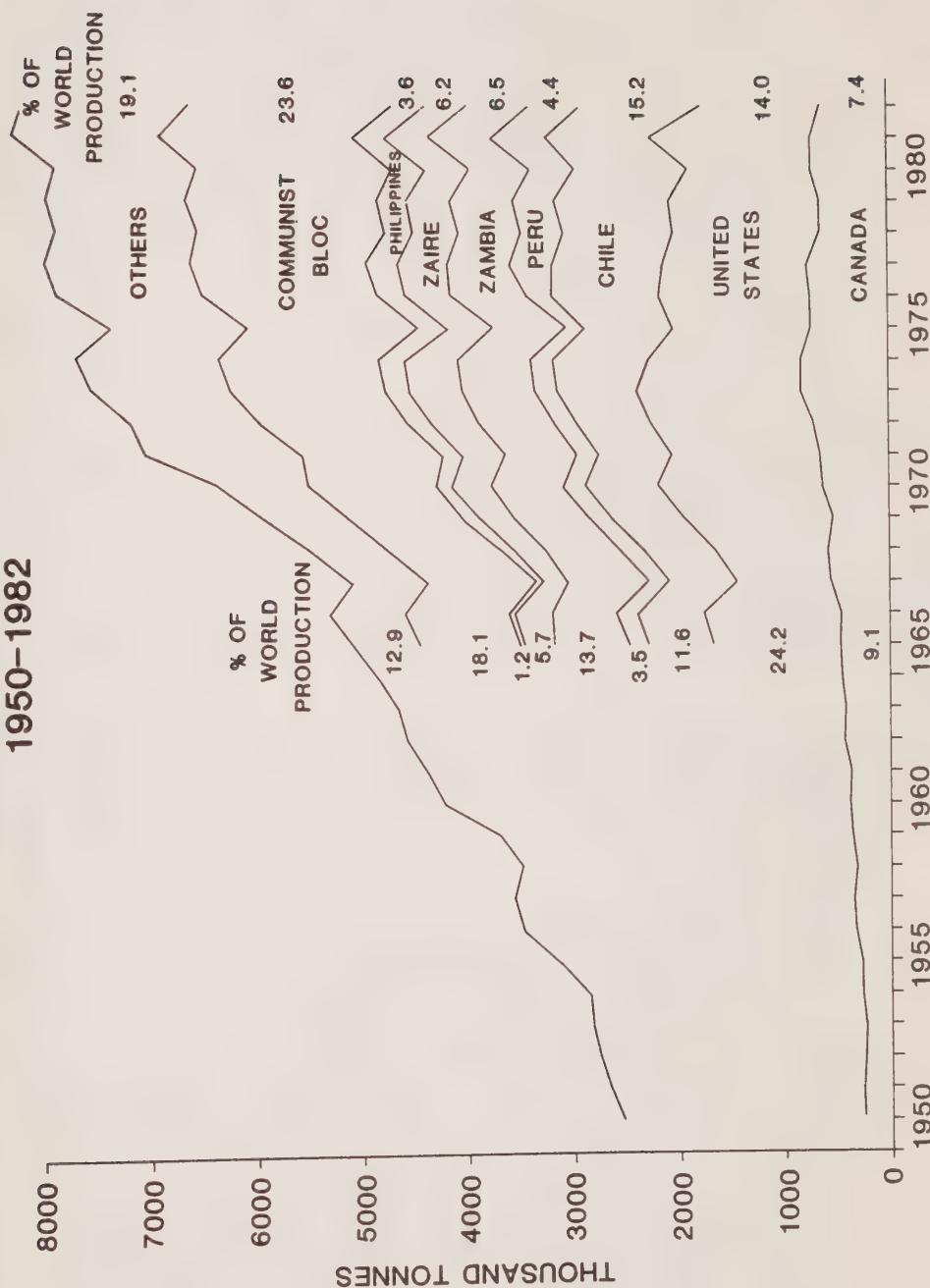
FIGURE 3.1

REFINED COPPER
PRODUCTION & CONSUMPTION
1950-1982



SOURCE: Mineral Policy Sector, EMR.

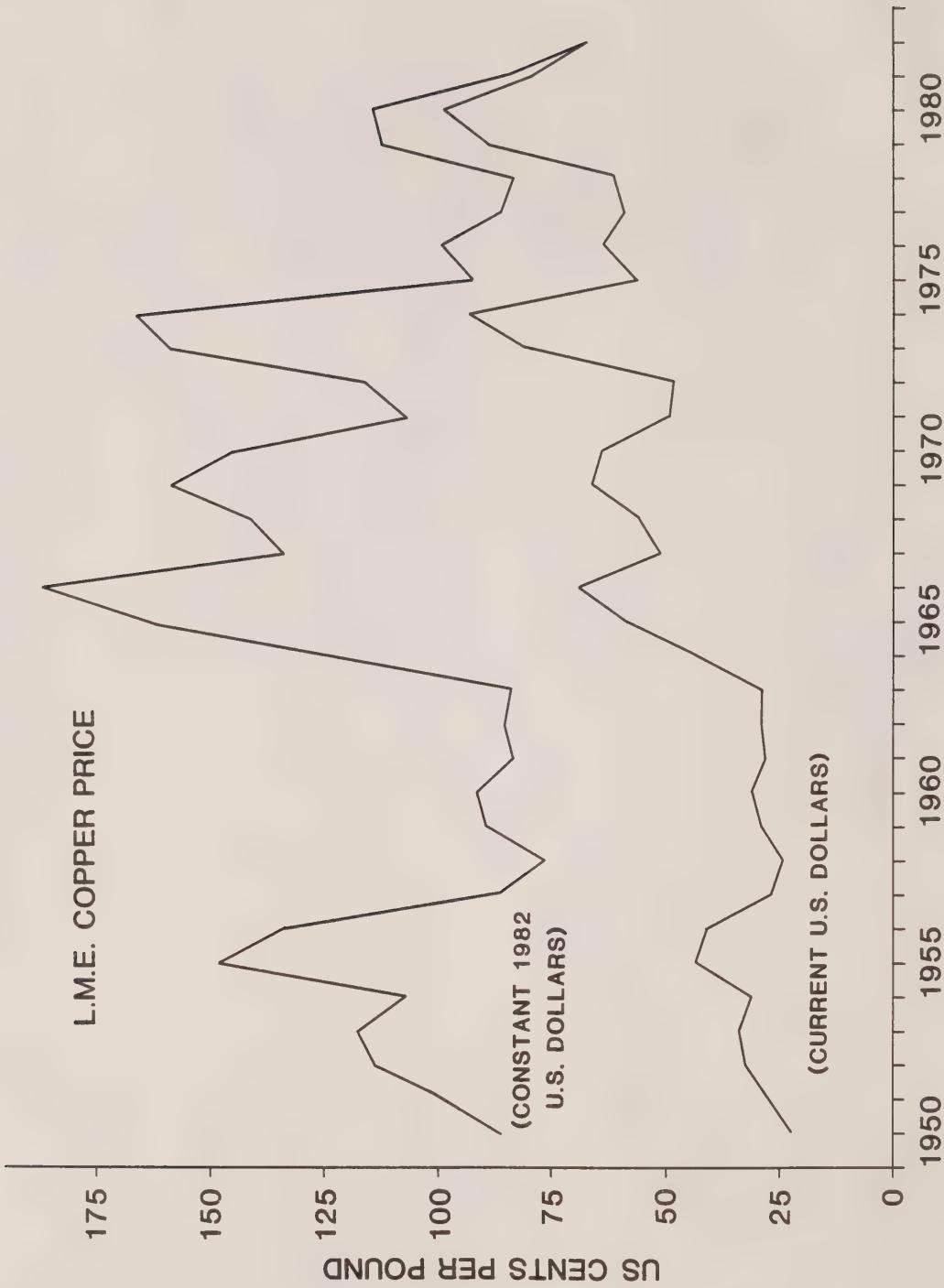
FIGURE 3.2
WORLD MINE
PRODUCTION OF COPPER
1950-1982



SOURCE: Mineral Policy Sector, EMR.

FIGURE 3.3

COPPER PRICE
1950-1982



SOURCE: Mineral Policy Sector, EMR.

CHAPTER IV

ENVIRONMENTAL ISSUES AND CANADA'S NICKEL AND COPPER SMELTING INDUSTRIES

This chapter reviews the major environmental issues confronting Canada's nickel and copper smelters today. The emphasis of the discussion will be on acid rain and the relative contribution of Canada's nickel and copper smelters to this important environmental problem. In addition, other issues such as particulate emissions and occupational health and safety are also briefly discussed.

THE PROBLEMS

Overview of the Acid Rain Issue

The phenomenon of acid precipitation, commonly known as acid rain, is acknowledged by scientists and governments to be one of the most pressing environmental issues facing widespread areas of eastern North America, western Europe and Scandinavia. Research attributes most of the acid rain in eastern North America to pollution from sulphuric and nitric acids. These acids are formed by a complex process, starting with emissions of sulphur and nitrogen compounds into the atmosphere. The acids are eventually deposited on the earth's surface either through precipitation or dry deposition. This can cause adverse environmental impacts, and in some areas severe environmental damage.

Based on emission data and on air trajectory modelling, acid deposition in eastern Canada from Canadian sources is estimated to equal the contribution from American sources located throughout the eastern United States. Eastern Canadian sources also contribute to acid deposition in the eastern United States.

In 1980, sulphur dioxide (SO_2) emissions from Canadian sources east of Saskatchewan were 4.5 million tonnes, of which the nonferrous smelter contribution was 45 per cent. Thermal power utilities and fuel combustion industries accounted for 16 per cent and 13 per cent, respectively, of total eastern Canada emissions.

The current Canadian policy objective is to reduce wet sulphate loading to moderately sensitive aquatic ecosystems to less than 20 kg/ha per year. To achieve this objective, a reduction in total SO_2 emissions of about 50 per cent is required in eastern Canada and the eastern United States. Canadian abatement action alone will not achieve the objective.

Canadian governments have taken action to address the acid rain problem. Ontario and Quebec environment ministers are committed to unilateral action to reduce SO_2 emissions in their respective provinces by 25 per cent by 1990, based on 1980 allowable emission levels. A further 25 per cent reduction by 1994 was also recently endorsed by federal/provincial environment ministers on March 6, 1984. As a result of this decision, Canadian emission reductions are no longer contingent on parallel action by

the United States. It has also been agreed by federal and provincial environment ministers that the federal government should take the lead role in developing an overall approach to achieve emission reductions by the nonferrous smelter sector, with provinces assuming a similar role with respect to the thermal power sector. A new working group of federal and provincial ministers of environment has also been established to determine how governments might assist, via supplementary measures, in ensuring stated goals are achieved within the chosen timeframe.

Because of the importance of the transboundary contributions to the Canadian and U.S. acid rain problem, in August 1980 Canada and the United States signed a Memorandum of Intent to negotiate a transboundary air pollution agreement. However, little progress has been made in concluding an agreement to date. Indeed the recent decision by the U.S. Administration not to implement a control program, but to spend additional monies on research and development to further delineate the problem, suggests that an agreement will not be forthcoming for at least one year and possibly longer. The decision to proceed unilaterally in reducing SO₂ emissions in Canada by 50 per cent by 1994 will give a clear signal to the United States of Canada's determination to address the acid rain problem. The federal government will continue to press the U.S. Administration for a similar commitment so that sensitive ecosystems in Canada can be protected.

Other Environmental and Health Concerns

Nonferrous smelters, in addition to emitting large amounts of SO₂ to the atmosphere, are sources of particulate metal emissions. For example, the Ontario/Canada Task Force on Sudbury Smelters reported that between 1973 and 1981, the smelters in Sudbury annually emitted on average about 1 800 tonnes of iron, 670 tonnes of copper and 500 tonnes of nickel. As to be expected, the deposition is mainly local, most of it recorded within a 50 km radius. In terms of impact, these emissions exacerbate the damage caused by acidity - in fact much of the recorded damage within 100 km of smelters is due to the effect of toxic levels of metals, either deposited directly or mobilized from the receiving environment by the increased acidity of the system.

The exposure of smelter workers to contaminants in the workplace is another issue which warrants attention. The contaminants include SO₂, dust and metal compounds. This is a problem for many of the smelters being studied.

In many respects, the modernization and/or depollution programs considered for each smelting operation will not only address the acid rain problem but also many other environmental concerns. However, control technologies in some smelter operations could bring on new environmental problems, such as localized acid mist and sulphur trioxide emissions from acid plants, and waste disposal, especially that containing contaminants such as mercury and arsenic, etc. These problems, however, are expected to be quite minor in comparison with the major advances that would be made on other fronts.

Nonferrous Smelters and the Acid Rain Problems

The nonferrous smelting industry is very much aware of the potential problems caused by unrestricted SO₂ emissions. Indeed, tens of millions of dollars have already been spent in developing new processing and pollution abatement technology. Significant modernization programs were implemented at a number of smelters in the 1960s and 1970s which served to enhance productivity while reducing emissions and contributing to improvements in local ambient air quality. At present, five of the eleven nonferrous smelting/refining establishments now operating in Canada contain over 90 per cent of their SO₂ emissions, and a further three control over 40 per cent. In 1983, only three nonferrous smelters in Canada remain uncontrolled (see Table 4.1). For the industry as a whole, containment of sulphur in concentrate approaches about 40 per cent on average.

Emphasis on smelter SO₂ containment can be very misleading. This is particularly the case for Canada's nickel industry. Because of the high sulphur to metal ratio in Canadian ores, rejection of sulphur to tailings at the milling or concentrate stage can be a very important means of controlling SO₂ emissions. In the case of Inco at Thompson, Manitoba milling techniques result in the rejection of about 45 per cent of sulphur contained in ore. Similarly, the percentage of contained sulphur in ore is 86 per cent at Falconbridge and about 70 per cent at Inco at Sudbury, Ontario. The latter statistics compare with smelter SO₂ containment percentages of 56 per cent and 44 per cent, respectively. The sulphur containment history for these three operations is provided in Figures 4.1 and 4.2. It is clear that all three have made significant progress in reducing sulphur emissions.

The major sources of SO₂ emissions in eastern Canada are the copper and nickel smelters located in Manitoba, Ontario and Quebec and also HBMS' zinc plant at Flin Flon, Manitoba. Actual and allowable 1980 SO₂ emission levels are detailed below:

<u>Smelter</u>	<u>1980 SO₂ Emissions</u> (tonnes)	
	<u>Actual</u>	<u>Allowable</u>
Inco - Sudbury, Ontario	812 000	1 155 000
Noranda - Noranda, Quebec	552 000	552 000
Inco - Thompson, Manitoba	215 000	414 000
HBMS - Flin Flon, Manitoba	248 000	293 000
Falconbridge - Sudbury, Ontario	122 000	154 000
Noranda - Gaspé	91 000	91 000
Total	2 040 000	2 659 000

According to Environment Canada, the importance of eastern Canada's nonferrous smelters to the resolution of the acid rain problem is further underscored by the fact that long-range air transport models show that their emissions contribute significantly to deposition in some sensitive areas in Canada. This is particularly the case for Inco

(Sudbury), Noranda and Falconbridge and much less so for the Manitoba and Gaspé smelters. In addition, it is generally acknowledged that for the Canadian economy as a whole, it is more cost effective to reduce SO₂ emissions from nonferrous smelters than from other sources. In developing a cost-effective solution to the acid rain problem, nonferrous smelters can therefore be expected to contribute a large share of SO₂ emission reductions than other emitters.

RECONCILING ENVIRONMENTAL AND ECONOMIC OBJECTIVES

There is growing consensus that timely and effective remedial action is required on the acid rain problem. According to Environment Canada, not only is extensive damage being done to the environment, but also many industrial sectors (e.g., forestry, fishing, etc.), which depend upon renewable resources are being affected by acid rain. However, with respect to the nonferrous sector, environmental objectives must be approached in recognition of the highly competitive and complex international market in which industry competes.

For example, it must not be forgotten that many of Canada's competitors, particularly those in the Third World, have not been and in the future are not expected to be required to adopt stringent emission control measures. In industrialized countries, such as Japan, western Europe and the United States, smelter emissions are more tightly controlled. However, in Japan and to a lesser extent Europe, trade barriers have been erected to protect domestic industries. In addition, sulphur byproducts can be sold at a profit in these countries. The smelting industries in both Canada and the United States do not have the advantage of such benefits. The repeated bills introduced in the U.S. Congress, calling for an environmental equalization duty of 10¢/lb on copper imports, provides a clear indication of the threat to competitive position that relatively more stringent environmental control poses for North American producers.

Canada's nickel and copper producers will be required to implement measures to reduce SO₂ emissions over the next ten years. These programs will be quite costly, particularly as they will come at a time when companies are under tremendous pressure to improve productivity and improve their overall financial position. These concerns, coupled with an uncertain market outlook, point to an urgent need by decision makers to carefully consider financial and timing factors in developing a strategy to achieve environmental objectives. These issues will be explored in greater depth in subsequent chapters.

TABLE 4.1

Sulphur Containment in the Canadian Nonferrous Smelting Industry, 1983

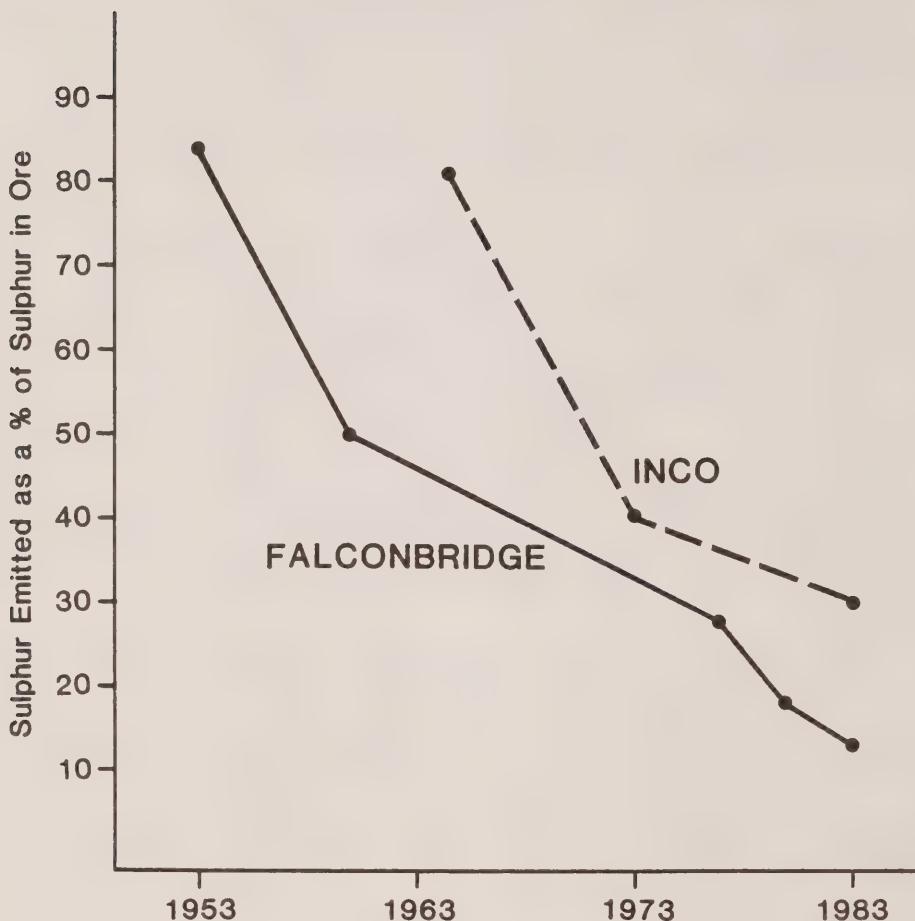
Smelter	Smelter Capacity (tpy)	SO ₂ Containment (%)	Sulphur in Ore Contained (%)
Afton Mines Ltd. ¹ Kamloops, B.C.	27 000 Cu	80+	N.A.*
Brunswick Mining and Smelting Corporation Limited Belledune, N.B.	63 000 Pb	95	N.A.
Canadian Electrolytic Zinc Limited Valleyfield, Que.	196 000 Zn	95	N.A.
Cominco Ltd. Trail, B.C.	144 000 Pb 247 000 Zn	94	N.A.
Falconbridge Limited Sudbury, Ont.	45 400 Ni 19 000 Cu	56	86
Hudson Bay Mining and Smelting Co., Limited Flin Flon, Man.	65 000 Cu 70 000 Zn	0	68
Inco Limited Copper Cliff, Ont.	126 000 Ni 138 000 Cu	44***	70
Inco Limited Thompson, Man.	54 000 Ni	0	45
Kidd Creek Mines Ltd. ² Timmins, Ont.	108 000 Zn 59 000 Cu	94	N.A.
Noranda Mines Limited Murdochville, Que.	65 000 Cu	59	**
Noranda Mines Limited Noranda, Que.	213 000 Cu	0	**
Sherritt Gordon Mines Limited ³ Fort Saskatchewan, Alta.	20 000 Ni	100	N.A.

Source: Internal report, Environment Canada.

1 Closed. 2 Copper smelter operational in 1981. 3 Hydrometallurgical process. * For those smelters with smelter containment greater than 80 per cent, the percentage of sulphur in ore contained is not available. ** These are essentially custom smelters. *** Assumes iron ore recovery plant at full operation.

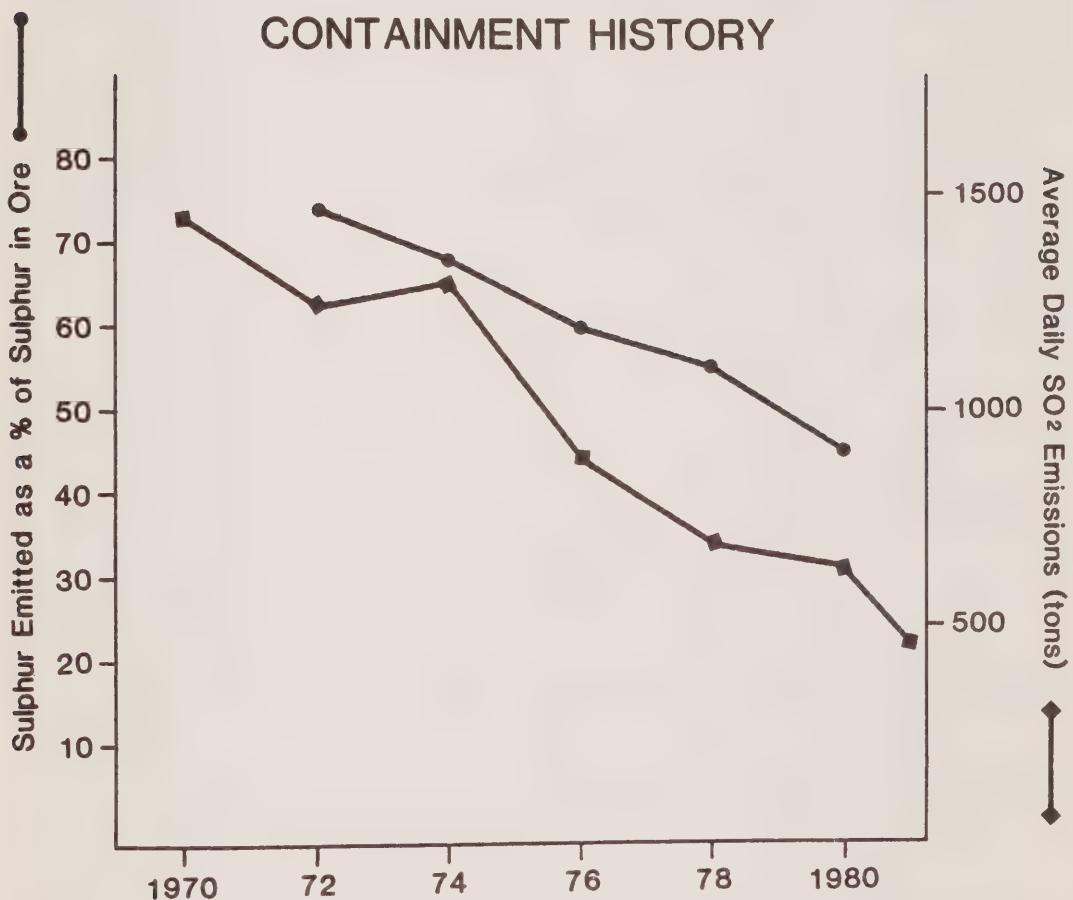
N.A. Not available; tpy tonnes per year.
Cu Copper; Pb Lead; Zn Zinc; Ni Nickel.

FIGURE 4.1
SULPHUR CONTAINMENT HISTORY
AT THE SUDBURY SMELTERS



SOURCE: Mineral Policy Sector, EMR.

FIGURE 4.2
INCO-THOMPSON SULPHUR
CONTAINMENT HISTORY



SOURCE: Mineral Policy Sector, EMR.

CHAPTER V

SULPHURIC ACID MARKET OVERVIEW

This chapter examines the market for sulphuric acid recovered from Canada's base metal smelters to the year 2000. Its purpose is to determine the potential market for new Canadian smelter abatement acid in North American markets and to estimate the price (netbacks) that Canadian producers could expect to realize on incremental acid sales over this time period. As discussed in Chapter VI, the modernization or sulphur fixation programs, which appear technically feasible in the short term, could result in 1.6 to 1.7 megatonnes of additional sulphuric acid production per year. The netbacks realized on future acid sales will be a critical factor in determining the overall economics of alternative investment programs at various smelter sites.

The discussion begins with a brief overview of the outlook for world and North American sulphur markets. This is followed by a review of North American sulphuric acid markets, with particular emphasis on those regional markets that are of particular interest to Canadian smelters.* Netbacks will then be estimated for each of the major eastern Canadian smelters, based on a marketing scenario that calls for the export of an additional 500 000 tonnes per year (tpy) in the northeast and midwest United States markets, with the remainder of byproduct acid sold in more distant markets. The emphasis on export sales reflects the limited scope for increased sales of sulphuric acid in the Canadian market.

The analysis presented below assumes that nearly all coal-fired electrical generating plants in the United States and Canada, that currently fix or which will be required to contain SO₂ emissions, will use one of the many scrubbing technologies that produce throw-away products. However, it must be recognized that in a number of cases, operators may choose alternative technologies, including those that recover sulphuric acid. The conclusions drawn in this chapter, therefore, must be tempered by the possibility of larger volumes of byproduct acid coming on-stream in our major market areas, which could have significant implications for netbacks realized by Canadian copper and nickel smelters.

SULPHUR SUPPLY AND DEMAND FORECAST

Global Overview

During the recent past, recovery of sulphur from oil refinery, sour gas processing and base metal smelting has expanded considerably. This trend is expected to continue in the future and will likely be

* The analysis presented on the outlook for sulphur draws heavily on reports prepared by Manderson and Associates for the Department of Regional Economic Expansion.

supplemented with sulphur from synthetic fuels and power plant fuel gas desulphurization. Nondiscretionary sources are expected to approach 60 per cent of the world supply by the year 2000 compared with only 46 per cent in 1975.

Reserves of Frasch sulphur (discretionary sulphur) in the United States are, with one exception, all nearing depletion in existing operating mines. Therefore, the importance of nondiscretionary supplies will become even more pronounced in North America than in the rest of the world. Expanding areas of world production will include Latin America, the Middle East and the U.S.S.R. Overall, world supplies are expected to grow at an average rate of 3 per cent per year through the year 2000, at which time available sulphur production from all traditional sources will be about 85 million tonnes.

World demand for sulphur will be increasingly dependent on the demand for phosphate fertilizers. Currently, the phosphate fertilizer industry accounts for in excess of 50 per cent of world sulphur production. This percentage is expected to increase to nearly 75 per cent by the year 2000, as demand by other traditional sulphur consuming industries is expected to remain relatively static. Overall, the world demand for sulphur is expected to grow marginally faster than supply and could approach 88 million tonnes by the year 2000.

The world supply-demand relationship over the longer term, and hence prices, will be quite sensitive to the timing of new increases in production, as well as to the occasional cyclical variations in demand (caused by industrial activity and by the demand for phosphate fertilizer). Although growth in demand is expected to outpace supply, the world is expected to be in a net surplus position throughout most of the forecast period. Periods of tight supply might develop in the mid-1980s, just before the Soviets bring on their large sour gas project, and are forecast to occur again in the mid to late 1990s. North America, Latin America and eastern Europe will have surpluses throughout the forecast period, while western Europe, Africa and Asia-Oceania will continue to have deficit positions (see Figure 5.1).

Any shortfalls in supply over the forecast period will likely be met in part by minor curtailment in demand by price adjustment or via drawdown of world inventory resources. In the early years to 1990, western Canada stockpiles of sulphur could help bridge supply-demand imbalances. Over the longer term, additional supplies from nontraditional sources, such as regeneration of sulphur at phosphate fertilizer plants, new Frasch activity and pyritic sources, could be brought on-stream in response to higher prices. Upward pressure on sulphur prices in real terms is not expected to materialize much before the mid-1990s. It should also be noted that sulphur prices will likely be more volatile in the future than they have been in the past. This is expected because of the volatility of fertilizer demand and the growing importance of nondiscretionary sulphur in the total supply picture.

North American Outlook

Canadian consumption of sulphur is expected to increase from 1.7 million tpy in 1980 to only 2.2 million tpy by the year 2000 (see Figure 5.2). The increased demand by the phosphate fertilizer industry in western Canada is expected to account for most of the growth in consumption. On the supply side, sulphur production in western Canada is expected to decline as the proportion of sour gas to sweet gas continues to fall. Smelter abatement acid is of course expected to increase substantially in eastern Canada.* Overall, Canadian sulphur or sulphur equivalent production is expected to fall from 7.5 million tpy in 1980 to 6.7 million tpy by 1990 and then increase to 7.3 million tpy by the year 2000. Canada will continue to be a major exporter of sulphur. Sulphur surplus to domestic requirements could approach a minimum 5.0 million tpy over the forecast period.

In the United States, sulphur demand is expected to increase from 14.1 million tpy in 1980 to 18.3 million tpy by the year 2000. Phosphate fertilizer industry is expected to lead the growth in U.S. sulphur consumption with most of the expected growth centred in Florida, North Carolina and to a lesser extent Idaho. The United States regions of most importance to Canada, e.g. the northeast and midwest, show little or no growth in sulphur consumption over the forecast period.

In the United States, sulphur recovery from refining will likely increase, especially on the Gulf Coast. Sulphur from sour gas processing is also called to increase during the forecast period, with the largest surge, by far, occurring in the western Overthrust region. Other sources of increase in the United States are base metal smelters, synthetic fuels (coal and oil shale) and flue gas desulphurization. Concurrently, however, annual U.S. Frasch sulphur production is forecast to drop off substantially from 6.4 million tonnes in 1980 to 4.4 million tonnes in 1990 and then to about 1.2 million tonnes by the year 2000. Overall, total U.S. sulphur production is projected to increase from 12.5 million tpy in 1980 to 16.5 million tpy by the year 2000. The United States is expected to continue to be a major importer of sulphur over the forecast period.

North America, as a whole, (including Mexico), is expected to continue to have a net surplus position in sulphur. In 1980, the three countries had a collective surplus of 5.2 million tonnes. This is expected to increase to 5.4 million tonnes by 1990 and to 5.6 million tonnes by the year 2000. The emerging supply demand balances are perhaps the most interesting feature of the North American sulphur market.

Previously deficit areas, such as the United States midwest and northeast, are expected to move closer to a net balance. Conversely, the Gulf Coast will likely move from a relatively large surplus to more of a balance, due to declining production from the Frasch industry. The western United States will continue to have large excesses of supply, particularly

* Manderson estimates that annual sulphuric acid production from eastern smelters will increase by 800 000 tonnes by 1990 and by a further 600 000 tonnes by the year 2000.

from Arizona base metal smelters. The same will be true for western Canada, but the surplus is expected to become smaller. In eastern Canada there will likely be a gradually increasing oversupply that, considered together with a decreasing deficit for sulphur in its primary export areas (i.e., the U.S. northeast and the United States upper midwest), could have negative implications for the marketers of byproduct acid.

Prices in North America

North American sulphur prices are historically referenced to discretionary Frasch producers' costs, with occasional divergence when either perceived or real world shortages occur. Despite their reduced share of the North American sulphur market, the Frasch producers are expected to have a continued influence on price. However, regional prices will continue to vary significantly due primarily to two factors: local supply-demand and transportation costs. For example, in a relatively remote area such as Alberta where large surpluses exist, prices will be lower than average. On the other hand, in consuming areas such as Florida and North Carolina, which are relatively far from adequate supplies, prices will be significantly higher than average.

Current and expected costs of producing Frasch sulphur are provided in the table below. Because fuel costs are expected to increase in real terms, and the unit usage of fuel to increase as sulphur reserves deplete, overall Frasch sulphur production costs are expected to increase at a rate slightly higher than the rate of inflation.

Frasch Sulphur Cost

	1980	1985	1990	1995	2000
	(current U.S. dollars)				
Fuel cost \$/MMBtu	2.50	4.30	6.90	11.25	18.00
Fuel use MMBtu/tonne	9.2	9.4	10.0	10.3	10.5
Fuel cost \$/tonne	23	40	69	116	189
Other variable costs	32	41	52	76	112
Fixed costs	10	11	12	13	15
Total \$/tonne	65	92	133	205	316
Inflation rate		5%			8%
1982 U.S. dollars	-	79	89	95	99

Note: In the above table, natural gas prices were escalated at about 10 per cent per year. This is based on Manderson and Assoc. estimates of average wellhead prices.

Based on a historical correlation between the ratio of the world demand to supply and the ratio of Frasch sulphur cost to the U.S. delivered price, an estimate of sulphur prices in various areas of interest can be derived. As seen in the following table sulphur prices are expected to fall slightly in real terms to 1990 (e.g., this reflects major new U.S.S.R. sour gas sulphur production) and rise from \$U.S. 118 (1982) to approximately \$U.S. 164 (1982) by the year 2000 in primary areas of interest to Canadian smelters (e.g., northeast and upper midwest states). The expected increase in the real price of sulphur will also be attributable to tightening supply-demand balances in the mid and late 1990s.

Sulphur Selling Price

Year	Primary Area
	1982 U.S. dollars/tonne sulphur
1980	99
1985	129
1990	118
1995	138
2000	164

SULPHURIC ACID MARKETS AND CANADA'S NONFERROUS SMELTERS

The majority of the world's requirement for sulphur is consumed in the form of sulphuric acid. This is a fortunate circumstance for byproduct acid producers, as it enables them to compete directly against acid from sulphur burning plants in the marketplace. However, in comparison to sulphur, sulphuric acid suffers a number of major disadvantages including high transportation costs, expensive storage costs and no energy value.

In North America, there is a large market for merchant acid, particularly in the United States. CIL Inc. has established a sizeable terminalling and transportation infrastructure in both Canada and the United States in support of direct participation in the merchant market. The company's investment in infrastructure includes unit trains and terminals at several locations around the Great Lakes, conferring an ability to serve its customers by overland and to a lesser extent water. CIL currently markets production from Falconbridge, Kidd Creek, Inco's operations in Sudbury, and Inland Chemicals in western Canada. At present, about 1 million tonnes of eastern smelter acid is marketed through the CIL network.

An alternative approach to marketing byproduct sulphuric acid is that illustrated by Noranda, which has entered into agreements with specific U.S. and Canadian companies to ensure outlets for its acid produced at Murdochville and Valleyfield, Quebec. Selling to a few specific large customers facilitates immediate entry to the market, requires a less sophisticated marketing, distribution and administrative network, but a more binding commitment between producers and the customers. In most contracts of this nature, prices are generally lower.

It is estimated that by the year 2000 some 43 million tonnes of sulphuric acid will be required in North America, an increase of about 6 to 8 million tonnes over 1980 reference levels. Unfortunately, the market area of most interest to Canada will remain static with all the growth taking place in the traditional phosphate fertilizer producing areas (Florida, North Carolina and Idaho). Any growth in Canadian acid sales to the northeast and upper midwest United States is expected to come only from the displacement of elemental sulphur sourced acid. However, this will only take place at concessional prices.

The market prospects are very similar in eastern Canada. Smelter acid is only likely to make major inroads in the Canadian market, if present sulphur burning plants are displaced. This of course assumes that no major new uses of acid are found in Canada (see Chapter VIII).

CIL currently serves a market that extends to a radius of 400 to 500 miles from Copper Cliff, Ontario. The company plans to extend its market radius over the next several years. A U.S. based sales company has been set up to administer the existing U.S. operation and to carry out sales effort. Provided acid is available, CIL has estimated that it can increase its sales in the U.S. market by 60 000 tpy, over an eight-year period, until reaching a plateau of some 500 000 tpy. It is believed that if the level of growth is pushed higher, serious downward pressure would be exerted on prices, which could prompt U.S. anti-dumping actions. Acid volumes in excess of 500 000 tpy would therefore have to be sold in more distant markets (using water borne transportation) unless alternative outlets were developed in Canada.

SMELTER NETBACKS ON SULPHURIC ACID SALES

It is very difficult to estimate with a high degree of confidence the netbacks that nonferrous smelters could expect on the large volumes of additional sulphuric acid production that would arise from further SO₂ containment programs. Uncertainty stems from a number of factors including:

- (a) the primary market area of interest is not expected to grow over the forecast period;
- (b) market penetration will be at the expense of existing producers-suppliers;
- (c) nondiscretionary sources of supply are expected to grow in importance in the United States;
- (d) prices for abatement acid must reflect lost energy credits for sulphur burning plants, and uncertainty in supply of smelter acid, given the cyclical nature of metal markets; and
- (e) transportation costs to other major sulphuric acid consuming markets are extremely high.

Average netbacks to Sudbury area smelters have ranged between \$C 10-18 (1982) over the last two to three years. Netbacks in the lower range were realized in late 1982 and 1983, when U.S. manufacturers suddenly reduced the list price of sulphuric acid from \$U.S. 95 a tonne to about \$U.S. 65 a tonne in the northeast U.S. market. This was done to protect market share during recessionary times. The upper range is representative of the kind of netback that could be available under stable market conditions. Over the longer term, it is possible that this range of netbacks could be applicable to Sudbury area smelters on 500 000 tpy of additional acid sales in the northeast and upper midwest United States. Indeed, with the expected tightening of world sulphur markets in the mid to late 1990s the upper bound of this price range could approach \$C 20 (1982).

Although this range of netbacks may be possible over the longer term, the question remains as to what it will cost Canadian smelters and merchants to gain a greater foothold in this large but essentially static market. Analysis of the cost structure of an existing sulphur burning plant suggests that the costs could be high, particularly if Canadian marketers are required to meet cash costs of sulphur burning plants in order to increase market share.

It is estimated that the cash costs of producing a tonne of sulphuric acid in a merchant sulphur burning plant in the primary market area approach about \$C 68 (1982) (excluding steam credits).* On the other hand, distribution charges in the United States, including a \$C 7 incentive to purchase, approach \$C 52 (1982) and the costs of transporting acid from Sudbury to the border are estimated at approximately \$C 30 (1982). Total distribution and transportation charges to penetrate and move a tonne of acid from Sudbury to the U.S. market could approach \$C 82 (1982). Under this pessimistic scenario, smelter netbacks in the Sudbury area could therefore fall as low as minus \$C -14 (1982) in order to displace sulphur burning plants in the primary market area and to increase sales by 500 000 tonnes.**

CIL's marketing plan entails a gradual and steady increase in acid sales over an eight-year period. Increased sales are expected to be achieved by encouraging some high cost sulphur burning plants to cease operation voluntarily. In this manner, CIL hopes that an indiscriminate price war can be avoided and prices kept above cash cost levels. It is anticipated that under this market scenario netbacks could be maintained in the range of \$C 10-20 (1982). Unit cost reductions in CIL's distribution system as a result of higher volume throughput would also help to support netbacks in this price range. However, it is recognized that some arrangements may have to be made to accommodate possible large deviations in supply or demand from this steady growth marketing scenario.

* It is believed that steam credits are not of great importance to small merchant sulphur burning plants, which are likely to be displaced under the 500 000 tonne marketing scenario.

** It should be noted that the merchant market is quite small and if larger volumes of sulphuric acid were forced into the market, realized netbacks could be much lower.

The above range of netbacks applies to an additional 500 000 tonnes of sulphuric acid sold in the northeast and upper midwest U.S. market. Acid production over and above this volume would have to be shipped out of this fragile market, incurring a potential penalty of \$C 25-35 (1982). Potential markets include North Carolina and Florida, the major phosphate fertilizer centres in the United States. However competition can also be expected to be severe in these markets, given that North America as a whole is forecast to be in a surplus sulphur position over the forecast period. Also this market is easily accessible by ocean transport from other major sulphur-producing regions such as Japan and Mideast and Latin American countries. Steam credits are also particularly important for sulphur burning plants serving the fertilizer industry, approaching some \$U.S. 15 per tonne of acid.

Estimated Netbacks to Eastern Canadian Smelters

	Netbacks per tonne (\$C 1982)
Inco, Sudbury	-15 to +20
Falconbridge	-15 to +20
Noranda (Horne)	-15 to +20
HBMS, Flin Flon	-45
Inco, Thompson	-50

The above table provides an estimate of the possible range of netbacks on incremental sulphuric acid production at each of the smelter sites of interest. These values will be used in Chapter VI to assess the benefits and costs associated with the various technical options under consideration. It is noted that netbacks for Sudbury area smelter acid could range from \$C -15 to +20 (1982). The upper end of this range would be applicable to the first 500 000 tonnes of new production. However, it is possible a further 700 000 to 800 000 tonnes of sulphuric acid could be brought on-stream from Sudbury area smelters over the forecast period. For these additional volumes, the lower end of the above range of netbacks could apply.

Netbacks on sulphuric acid sales of \$C -45 and \$C-50 (1982) have been estimated for the HBMS and Inco Thompson operations, respectively. In deriving these estimates, it was assumed that acid production from the Manitoba smelters would be over and above the 500 000 tonnes that can be assimilated into the primary market area. This new acid would therefore have to be shipped outside this fragile market area, and in so doing it would incur a major economic penalty. The above netbacks also reflect the additional transportation costs of moving acid from northern Manitoba to distribution points on the Great Lakes.

SUMMARY COMMENT

The projected range of netbacks for additional smelter acid, and in particular acid surplus to the 500 000 tonne-market scenario, is very unattractive. Indeed, for most plants the realized netbacks would fall well short of the costs of producing the acid itself. This clearly points to a need to consider developing alternative technologies to enhance the value of the sulphur byproduct or reduce the cost of producing sulphuric acid. This is explored in greater depth in Chapter VIII.

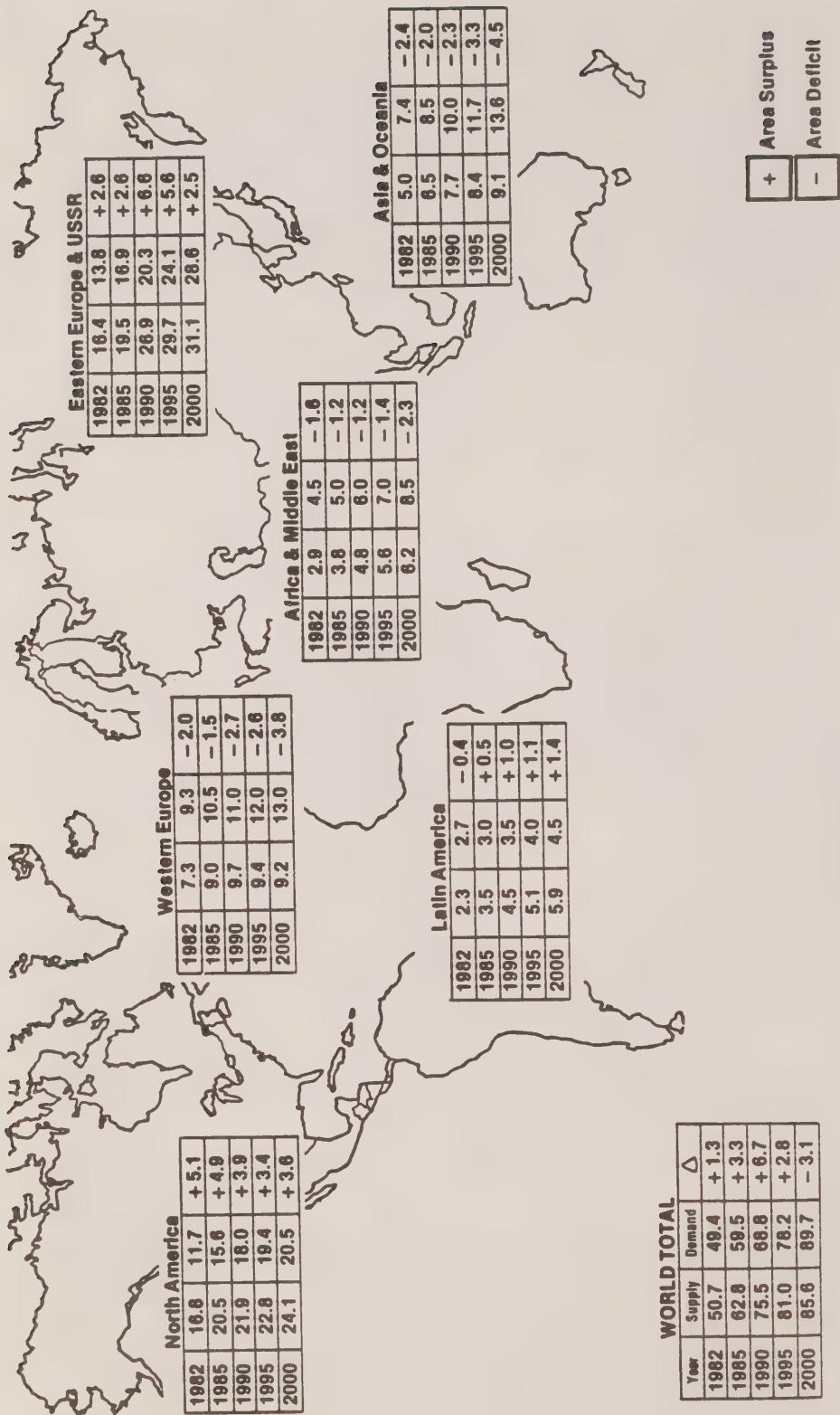
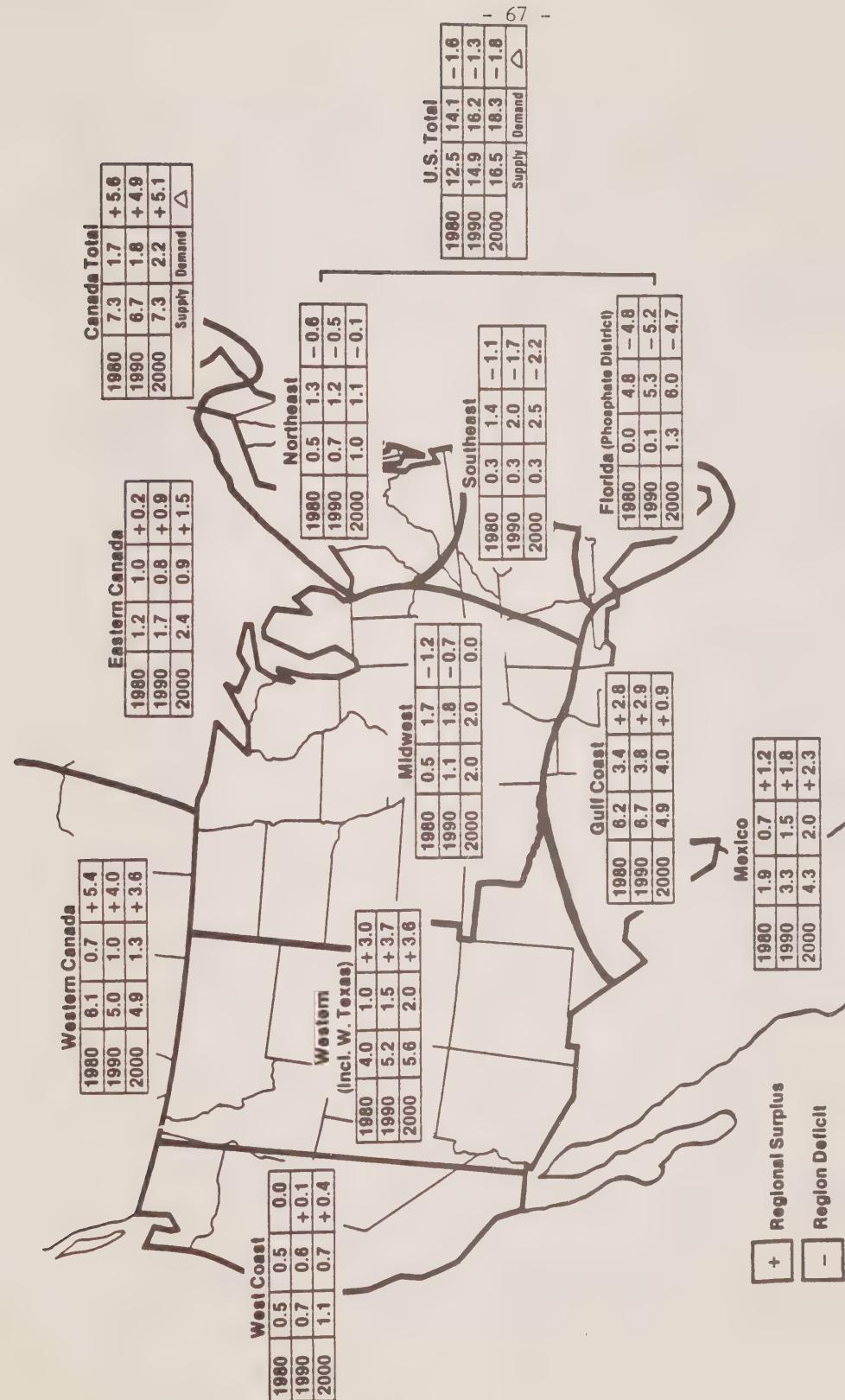


FIGURE 5.1
RECENT & PROJECTED FREE WORLD SULPHUR SUPPLY — DEMAND RELATIONSHIP,
BY AREA — SELECTED YEARS, 1982-2000
(In Millions of Metric Tons of Sulphur Equivalent)

SOURCE: Manderson Associates Inc.



PAST & PROJECTED SULPHUR SUPPLY — DEMAND RELATIONSHIP, BY REGION IN
NORTH AMERICA & MEXICO : 1980, 1990 & 2000
(In Millions of Metric Tons of Sulphur)

SOURCE: Manderson Associates Inc.

FIGURE 5.2

CHAPTER VI

TECHNOLOGICAL REVIEW AND ASSESSMENT

This chapter examines, on a plant-by-plant basis, the various modernization and/or sulphur fixation alternatives available to Canada's nickel and copper smelters that appear technically feasible in the short term. Each alternative will be described and its impact on plant productivity and pollution control briefly assessed. The operations studied include: Inco (Sudbury), Inco (Thompson), Falconbridge, Noranda (Horne), HBMS (Flin Flon).

For each operation, a base case was established following which the incremental impacts of modernization and sulphur fixation alternatives were estimated. The analyses presented here draw heavily on past technical studies in this field. Individual companies were also extensively consulted on all technical issues. Notwithstanding these contributions, Energy, Mines and Resources assumes full responsibility for the cost estimates in this report.*

The focus of this chapter is on those technologies that appear feasible in the short term. However, considerable effort was also made to identify, on a plant-by-plant basis, longer term, higher risk alternatives that offer potentially more attractive solutions to the problems faced by Canada's nonferrous nickel and copper smelting industries. The findings of this work are provided in Chapter VII.

INCO - SUDBURY

This is a very large, complex, nickel-copper smelter. The nickel circuit, which was built in 1930, uses multi-hearth roasters, reverberatory furnaces and conventional Peirce-Smith converters. Because of the dated technology employed, smelter operating costs have been high. However, recent productivity improvements have made the existing process competitive with more modern smelting technologies. Nonetheless, the smelting process remains energy inefficient, as it does not take advantage of the sulphur fuel in concentrate. Consequently, carbonaceous fuel requirements are high.

At present, all of the SO₂ produced in the nickel smelter is vented to the atmosphere. About 90 per cent of the total sulphur in the concentrate is removed as SO₂ in the smelter, 50 per cent from the roaster-reverb and 40 per cent from the converters. Most of the remaining 10 per cent is removed as SO₂ from fluid bed roasting of the high-grade nickel sulphide concentrate at a subsequent refining stage. The multi-hearth roaster, reverb furnace and converter gas streams are too dilute

* The reader should note that for most operations, the cost estimates provided in this report should only be considered accurate within a range of between ±25 to 30 per cent.

and/or too variable for efficient capture and conversion in an acid plant. Therefore, there is little that can be done economically with the existing smelting process to significantly increase SO₂ capture or improve energy efficiency. Productivity improvements and SO₂ containment will necessitate replacement with more modern technology and/or significant modifications of existing equipment.

Inco has developed a new flotation process for increasing the efficiency of pyrrhotite separation from the bulk nickel-copper concentrate. The objective is to increase pyrrhotite rejection (PR) from the ore to 90 per cent from the current 80 per cent. This will result in an increase in the nickel content of the nickel concentrate to about 14 per cent from the current 11 per cent and in a 20 per cent reduction in smelter SO₂ emissions. The new PR process will also reduce smelter operating costs because of the higher nickel output per unit of throughput. Although nickel recoveries will be slightly lower because of nickel losses in the PR process, the overall advantages should more than offset the disadvantages of having to mine and process more ore to achieve the same nickel production. The capital cost of pyrrhotite rejection is also very low compared with alternative methods for reducing SO₂ emissions from the nickel smelter.

Inco's iron ore recovery plant (IORP) was originally built in 1955 to recover nickel, iron ore and sulphuric acid from pyrrhotite. Pyrrhotite contains less than 1 per cent nickel, of which about 75 to 80 per cent is recovered in the process. Economic operation of the unit is highly dependent on obtaining favourable prices for iron ore pellets and sulphuric acid. Because of weak markets and high operating costs, the IORP is uneconomic to operate for iron and nickel recovery and is presently being operated only to fulfill contractual commitments for sulphuric acid. From a modernization standpoint the main interest in the IORP is that it contains fluid bed roasters, which permit SO₂ capture in contact acid plants. Utilization of this equipment will be very important in Inco's nickel circuit modernization plans.

On the copper side, Inco flash smelting technology has been in use since 1952 but nevertheless represents a modern, very efficient technology. Two Inco flash smelters are presently being built in the United States. In the smelter, concentrate is injected with pure oxygen in a "flash chamber" to produce a 45 to 55 per cent copper matte, a discard slag and a 70 to 80 per cent SO₂ gas, which is recovered and sold as liquid SO₂. Because the SO₂ concentrations are so high, gas handling and cleaning costs and SO₂ recovery costs are minimal. The process is also exceptionally energy efficient, requiring essentially no carbonaceous fuel, except to pre-dry the concentrate.

The flash smelter matte is converted to blister copper by air blowing in conventional batch converters to remove additional sulphur and slag-off most of the remaining iron. The blister copper is further refined in anode furnaces to reduce the oxygen level, prior to casting into anodes for electrorefining. Converter slag, which contains appreciable copper but also most of the nickel present in the copper concentrate, is recycled to the nickel smelter for both nickel and copper recovery. The batch conver-

sion process results in 45 to 50 per cent of the sulphur in the concentrate being released as a variable concentration, variable flow SO₂ gas stream, which is cleaned and vented to atmosphere.

Modernization/Sulphur Fixation Alternatives

Only two options were examined, one each for the nickel circuit and the copper circuit. In both cases, it is assumed that the new pyrrhotite rejection process is fully operational, and that nickel production is 280 million lbs/year. The analysis is based on pre-1983 operations and does not take into account cost cutting measures, which Inco has implemented in the last year or so.

1. Roast Reduction Smelting

Based on the knowledge and experience gained in electric furnace smelting at Inco's Thompson, Manitoba smelter. Inco has developed and tested, on a large scale, a new fluid bed roast-electric reduction smelt (RRS) process, which is capable of removing up to 80 per cent of the total sulphur in the concentrate in a high strength (>10 per cent) SO₂ gas stream from the fluid bed roasters. The electric furnace is operated under reducing conditions to produce a high-grade (about 50 per cent) nickel-copper matte and a discard slag. Conventional batch converting is then used to produce a final matte grade of 75 to 80 per cent. Converter slag is recycled to the electric furnace. Recovery of nickel and cobalt in the process is said to be better than with the present process. The RRS has the potential to efficiently recover 80 per cent of the total sulphur in the nickel concentrate as acid. Of the remaining 20 per cent, approximately half is divided equally between electric furnace gases and converter gases that are too dilute and too variable, respectively, for efficient conversion to acid. The remainder leaves the smelter in bessemer matte.

In implementing the RRS, Inco will attempt to use its existing buildings and equipment as much as possible in order to minimize capital costs. The option considered here assumes that the Iron Ore Recovery Plan (IOPR) will not process pyrrhotite, but that the IOPR roasters and acid plants will be used in the RRS process. The new smelter, consisting of new electric furnaces and converters will be located at the east end of the existing smelter site. This plan will require the development of a transportation system to get the roaster calcine to the smelter site.

Implementation of the RRS would improve nickel and cobalt recovery by 2 per cent and 28 per cent, respectively. In addition, smelter operating costs would decrease. Oil and natural gas fuels would be replaced with electric power and coke. SO₂ emissions would be reduced from 770 000 tpy to 320 000 tpy or by some 450 000 tpy (59 per cent). Sulphuric acid production would be about 665 000 tpy based on a 280 million pound per year nickel schedule.*

* The reader should note that this level of acid production should not be considered incremental or additional to present acid production volumes at Inco, Sudbury. As the RRS is implemented, present acid production at the IOPR, based on pyrrhotite roasting, would be phased out. Present production volumes range between 300 000 to 400 000 tonnes.

Capital cost requirements are estimated at \$C 430 million (1982). Operating cost savings could approach \$C 20 million (1982) per year. Since improved nickel recovery in the smelter would result in less ore being required to maintain nickel production levels at 280 million lb/year, approximately 50 to 55 per cent of total operating cost savings would be attributable to lower mining-milling costs. Most of the other savings would be due to lower labour costs in the nickel smelter.

When compared on the basis of constant nickel output, there is virtually no increase in metal revenues attributable to the RRS process. Lower overall ore requirements result in less byproduct credits per pound of nickel produced, which offset the increased cobalt credits arising from improved cobalt recovery with the RRS. Any incremental revenues, therefore, are dependent entirely on sulphuric acid sales. Acid revenues could range from \$C -10 to +14 million (1982) year, assuming a \$C -15 to +20 (1982) net back per tonne of acid, respectively (see Chapter V).

Total maximum incremental benefits are therefore estimated to be \$C 34 million a year. This translates into a discounted cash flow pre-tax rate of return of approximately 5 to 6 per cent, in real terms.

2. Manufacture of Sulphuric Acid from Copper Converter Gases

This option involves the installation of tight-fitting primary and secondary hoods on the copper converters. The primary hood would collect converter off-gas at an SO₂ concentration level adequate for acid making. A ducting system would take the off-gases from the hoods to a new acid plant at the smelter. The secondary hoods are required to maintain an acceptable work place environment. The gases from these hoods would be directed to the 381-m stack. It should be noted that high strength copper flash furnace off-gases in excess of the existing liquid SO₂ plant capacity (100 000 tpy) have not been considered in our analysis. However, it would obviously also be beneficial to design the new acid plant and the associated ducting to capture these high strength SO₂ gases.

There is considerable doubt that efficient SO₂ capture from the converters can be maintained because of problems associated with recovering nickel from the converter slag. In addition, acid plant operating costs will be high because of the low concentration and variable nature of the gas. The only reason for considering this option is that there are no other short-term alternatives for reducing SO₂ emissions from the copper smelter.

Hooding of converters would result in the capture of about 95 per cent of converter gases, which would result in a further decrease of 23 per cent in SO₂ emissions or 180 000 tpy. Corresponding sulphuric acid production would be about 280 000 tpy.

Capital costs associated with this project could approach \$C 120 million (1982). Operating costs in the copper smelter would increase by about \$C 5.5 million, (1982). Additional revenues from sulphuric acid sales could range from \$C -4.2 to \$5.6 million (1982), assuming a \$C -15 to

+\$20 (1982) netback on acid sales, respectively. This option offers no economic incentive. Implementation would impose an additional cost burden on Inco's Sudbury operation.

Hooding of converters is a very unattractive sulphur fixation option. The RRS option is considerably more attractive, but the return on capital is marginal at best. Indeed as a result of various cost cutting measures undertaken by Inco over the last year, it is quite possible that the incremental benefits, which have been estimated for the RRS, could be lower than those documented. Inco officials believe the only benefits associated with the RRS would be improved metal recoveries. Labour cost savings in the smelter would be minimal. Inco is investigating ways to reduce the capital costs of this project and in so doing elevate the status of the RRS from an environmental control project to a more economic undertaking.

INCO - THOMPSON, MANITOBA

Inco's Thompson, Manitoba Division is one of the world's largest fully integrated nickel mining, milling, smelting and refining complexes. The smelter is relatively modern, employing fluid bed roasters, electric furnaces and Peirce-Smith converters to produce a nickel sulphide matte for electrolytic refining.

The most serious problem at the Thompson operation today is continuing substantial emissions of SO₂ to the atmosphere. At present, sulphur containment for the operation as a whole is limited to pyrrhotite rejection. Currently about 45 per cent of sulphur in ore is rejected to tailings prior to the concentrate entering the smelter. The replacement of the Pipe open pit with the Thompson open pit in the near future could result in this percentage dropping to about 28 per cent. However, Inco currently has an extensive development program in place and company officials are confident that with improved pyrrhotite rejection 50 per cent of sulphur in ore can be rejected to tailings when the Thompson open pit is slated to come on-stream in 1986.

The breakdown of SO₂ production in the smelter is as follows: roasters - 50 per cent, electric furnaces - 20 per cent and converters - 30 per cent. The roasters produce a high-grade SO₂ gas averaging at least 7.5 per cent SO₂, which is quite suitable for SO₂ fixation as acid. The electric furnaces produce a very weak gas stream, which is not amenable to efficient capture and containment. The converters produce a variable strength, intermittent gas stream, due to the batch nature of the process.

Modernization/Sulphur Fixation Alternatives

The major issue at the Thompson smelter is sulphur fixation. Consequently, the technological options examined for the facility were fixation of roaster gases and of roaster and converter gases using conventional acid plant technology. Application of Inco's RRS process to the Thompson facility was also examined for comparative purposes. Each of the options studied assumes a smelter production rate of 50 000 tonnes of metal per year and a sulphur in ore rejection rate of 50 per cent.

1. Manufacture of Sulphuric Acid from Roaster Gases

Under this option, 100 per cent of the roaster gases from the smelter would be directed, via new high velocity flues and new electrostatic precipitators to a single absorption acid plant. SO₂ concentration in gas streams would be maintained at 7.5 per cent or better. The acid plant, using standard conversion technology, would achieve an average annual conversion efficiency of 96 per cent.

Control of roaster gases would reduce smelter emissions from 225 000 tpy to 120 000 tpy, a decrease of 46 per cent. Corresponding sulphuric acid production would be 159 000 tonnes.

Acid plant and accessory costs would require an investment of \$C 46 million (1982); operating costs would increase by \$4.3 million (1982); and, assuming a \$C -50 (1982) per tonne netback on sulphuric acid sales, plant revenues would decrease by about \$C 8.0 million (1982). This option, therefore, would require a \$C 12.3 million (1982) annual operating loss to be absorbed by the operation.

2. Manufacture of Sulphuric Acid from Roaster and Converter Gases

Roaster gases would be captured as in option 1. above. Converter gases would be captured by utilizing new tight fitting primary hoods, with secondary hoods for work place environment control. Fumes from the secondary hoods would be vented to the smelter stack. Gases from the primary hoods would be directed via new high velocity flues and new electrostatic precipitators to a common flue-feeding roaster and converter gases to a single absorption acid plant. The acid plant would achieve a 96 per cent average conversion efficiency and be sized to process 100 per cent of the roaster and converter gases.

Control of roaster and smelter gases would reduce smelter emissions from 225 000 stpy to 51 000 tpy, a decrease of 84 per cent. Corresponding sulphuric acid production would be 265 000 tpy.

Capital costs associated with this option would approach \$C 95 million (1982). Operating costs would increase by \$C 7.9 million (1982) per year and revenues would decrease by some \$C 13.3 million (1982) per year (assuming a -\$50 netback per tonne on sulphuric acid sales) for a total annual operating loss of \$C 21.2 million (1982).

3. Roast Reduction Smelting

This is the same technology examined for the nickel circuit at Inco (Sudbury). The principal advantage of RRS application at Thompson would be the substantial reduction in the proportion of SO₂ emitted in electric furnace and converter gases. It is estimated that 84 per cent of the sulphur in concentrate would be emitted as a continuous gas stream from the roaster at a concentration suitable for fixation as sulphuric acid. Since metal recoveries by standard electric smelting techniques at Thompson are already high, implementation of the RRS would have only moderate potential for further improvement in metal recoveries.

The implementation of the RRS would require substantial modifications to the existing smelter, including replacement of existing roasters by larger units. A number of other changes would also have to be made. Roaster gases would be directed to a new acid plant as in option 1. However, in this case, the acid plant would need to be twice as large.

The RRS technology would result in a reduction of SO_2 emissions from 225 000 tpy to 29 000 tpy or a decrease of 87 per cent. Corresponding sulphuric acid production would be 306 000 mty.

Capital expenditures of \$C 125 million (1982) would be required to implement the RRS process at Thompson. Operating costs would increase by \$7.7 million (1982) per year. Improved cobalt recovery would generate additional revenues of \$0.5 million (1982) per year. However, this increased revenue would be more than offset by losses on acid sales, which could approach \$C 15.3 million (1982), assuming a \$C -50 (1982) tonne net-back. The overall incremental impact on net operating earnings of this option would be about \$C -22.5 million (1982) per year.

None of the sulphur fixation options studied for Inco Thompson are attractive in economic terms. All add significantly to unit operating costs.

NORANDA HORNE SMELTER

The Horne smelter is one of the world's largest custom copper smelters. The facility presently operates with one process reactor, one wet-charge reverberatory furnace and three Peirce-Smith converters. Two oxygen plants with a total capacity of 590 st/d provide oxygen enrichment to both the reactor and reverberatory furnaces.

The Noranda reactor is a modern, efficient technology. It has direct operating costs below most other custom smelters in the world. However, despite oxygen enrichment, the reverberatory furnace is a high cost operation. Noranda continues to operate the reverberatory furnace in order to give flexibility to its overall operation and to maintain smelter capacity. More specifically, the reverberatory gives the Horne the ability to process complex concentrates, especially those high in bismuth and antimony, which cannot be adequately handled by the reactor.

Excluding market and transportation cost considerations, the other major continuing problem with the present operation is the emission to atmosphere of substantially all of the sulphur in concentrate feed as sulphur dioxide. The exhaust gas concentrations range from ideal for sulphur fixation (process reactor) through difficult but possible (converters) to totally unsuitable (reverberatory furnace). At full production capacity of 491 000 tpy dry concentrate for the reactor and 372 000 tpy dry concentrate for the reverberatory furnace, total SO_2 emissions for the plant would approach 560 000 tpy.

Modernization/Sulphur Fixation Alternatives

Two technological options to control sulphur emissions were studied: control of reactor gases; and, control of reactor and converter gases, both employing conventional acid plant technology.

1. Manufacture of Sulphuric Acid from Reactor Gases

Reactor gases would be directed to a single contact acid plant. SO₂ concentrations would be maintained at 8 per cent. Mercury removal and weak-acid treatment facilities would also be required.

Control of reactor gases would reduce SO₂ emissions by about 43 per cent or 240 000 tpy at full production capacity. Corresponding sulphuric acid production would be 370 000 tpy.

Total capital costs associated with this project would be at least \$C 80 million (1982). Operating costs would rise by almost \$C 5.2 million (1982) per year. Assuming netbacks of \$C -15 to \$C +20 per tonne (1982), sulphuric acid revenues could range between \$C -5.5 to \$C +7.4 million (1982) per year.

2. Manufacture of Sulphuric Acid from Reactor and Converter Cases

Converter gases would be captured by utilizing new tight fitting waffle hoods. Gases would be directed via new high velocity flues and new electrostatic precipitators to a common flue, feeding reactor and converter gases to either one or two single contact acid plants.

Control of reactor and converter gases would result in a 64 per cent reduction in SO₂ emissions or 358 000 tpy. Corresponding sulphuric acid production would be 550 000 tpy.

Total capital cost of this project would depend on the number of acid plants required. Estimates range from \$C115 to \$C150 million (1982). Operating costs could increase by about \$C7.5 million per year. Sales from sulphuric acid could range from \$-8.3 million to \$11.0 million per year.

Based on the above analysis it appears that there is no economic incentive for Noranda to proceed with sulphur fixation at the Horne.

FALCONBRIDGE

Falconbridge Sudbury operation is a major integrated nickel-copper mine, mill and smelter operation. The product of the smelter is a matte containing 41 per cent nickel and 31 per cent copper that is shipped to a Falconbridge subsidiary in Norway for refining, and recovery of nickel, copper and various precious metals contained in the matte. Completion of the Smelter Environment Improvement Program in 1978 has resulted in a very modern and efficient facility. Like Inco Thompson, the smelter uses fluid bed roasters, electric furnaces and Peirce-Smith converters. An acid plant has also been constructed with a design capacity of 1 180 tonnes of 100 per cent sulphuric acid per operating day.

Falconbridge has just recently completed a major R&D project which increases sulphur elimination and capture to 56 per cent from 50 per cent during the roasting process. This development will permit Falconbridge to capture and control 86 per cent of the sulphur contained in ore, at an 88 million lb/year production rate, and to reduce total emissions of SO₂ into the atmosphere to about 124 000 tpy. This represents a reduction of about 32 000 tpy (20 per cent).

Modernization/Sulphur Fixation Alternatives

The major issue at the Falconbridge smelter is still SO₂ containment. Although the company is significantly advanced in its environmental improvement program, there still remains scope for further reductions. The sulphur fixation options examined below assume an 88 million lb/year production rate, a 50 per cent roast and SO₂ emissions of 156 000 tpy.

1. Increased Pyrrhotite Rejection

It is generally acknowledged that the least expensive method of reducing SO₂ emissions is by rejecting more sulphur to tailings and increasing the metal grade of concentrate. At present, Falconbridge produces 6.2 per cent nickel in concentrate. The objective of this option would be to increase the nickel concentrate grade to the 7.3 to 8.5 per cent range, by installing a pyrrhotite rejection process. The upgrading would be accomplished by floating less pyrrhotite with the copper-nickel concentrate and/or magnetically separating more pyrrhotite from these sulphides. A major benefit would be reduced smelter operating costs. In addition a further 15 to 27 per cent reduction in SO₂ emissions could be achieved. Production of higher grade nickel concentrates however would result in decreased nickel and byproduct recovery requiring more ore to be mined and milled per unit of nickel output and therefore increased mining and milling costs. The ultimate life of the orebody would be shortened, unless processes were developed to economically recover the metal values lost in the pyrrhotite.

To achieve an 8.5 per cent nickel concentrate, capital expenditures of \$C 12 million (1982) would be required to construct a new mill. Incremental revenues of \$C 4.2 million (1982)* could be generated as

* It should be noted however that the above incremental revenue of \$4.2 million (1982) is generated at the expense of substantial metal losses resulting from the pyrrhotite rejection process. These losses of nickel and associated byproducts, which Falconbridge would normally recover if pyrrhotite rejection was not implemented, are estimated to have a gross value of about \$C 24.5 million (1982) and a net value, after additional operating costs have been accounted for, of about \$C 11.5 million (1982) per year. Pyrrhotite rejection therefore, when assessed on the basis of constant ore input (rather than constant nickel output) results in a real loss in revenue to Falconbridge of about \$C 7 million per year (1982), excluding any credits or losses associated with increased sulphuric acid production. This loss can be recovered in the future only if an economically viable process can be developed for treating pyrrhotite. It is extremely important, therefore, to ensure that metal losses during pyrrhotite rejection are minimized and that pyrrhotite tailings are stored separately from main mill tailings to facilitate easy access for future processing.

increased byproduct metal output would occur as a result of having to process more ore to maintain nickel production levels. Additional mining-milling operating costs would approach \$8 million (1982) per year; however reductions in smelter operating costs could approach \$5 million (1982) per year. Not accounting for the shortened lifespan of the orebody, increased pyrrhotite rejection could therefore result in an incremental annual pretax benefit of \$1.2 million (1982). Smelter emissions could be reduced by up to 42 000 tpy.

2. Manufacture of Sulphuric Acid from Converters

Converter gases would be captured by installing close fitting primary hoods. Secondary hoods for workplace environmental control would also be required. Gases would be directed via high velocity flues and electrostatic precipitators to a gas mixing chamber where clean converter gases would be blended with roaster gases and fed to an acid plant. A second acid plant, having a high degree of flexibility to changing gas concentrations and flows, would need to be constructed.

Control of converter gases would achieve about 95 per cent capture of roaster and converter SO₂ gases, increasing recovery of sulphur contained in concentrate to about 90 per cent. SO₂ emissions would be reduced by 96 000 tpy and sulphuric acid production increased by about 47 per cent or 144 000 tpy.

Capital costs associated with this option would approach \$C 70 million (1982). Additional operating costs of \$C 3.3 million (1982) per year would also be incurred. Additional acid revenues could approach \$C -2.2 to \$C +3.0 million (1982) per year assuming a \$C -15 to \$C +20 per tonne (1982) netback, respectively.

3. Manufacture of Sulphuric Acid from Converters and Electric Furnaces Using SO₂ Absorption/Regeneration Process

Implementation of this option requires changes in the ducting from the converters and electric furnaces to reroute gases to a new citrate scrubbing plant. Major modifications are also required to the contact section of the acid plant to handle the higher strength SO₂ gas streams. An additional water cooling tower system would also be required.

This option would bring total capture of sulphur in smelter feed to about 96 per cent. SO₂ emissions would be reduced by 140 000 tpy and sulphuric acid production increased by 214 000 tpy.

Capital costs associated with this alternative would be about \$C 51 million (1982). Additional operating costs of about \$C 13.7 million (1982) per year would be incurred. Increased revenue from acid sales could range from \$C -3.2 to +4.3 million (1982) per annum.

4. Roast Reduction Smelting

The RRS process was also examined. Capital costs to implement this option were estimated at \$C 67 million (1982). Operating costs would increase by at least \$C 10 million per year. Under this option SO₂ emissions would be reduced by about 122 000 tpy (78 per cent) and sulphuric acid production increased by 185 000 tpy over the base case. It is estimated that metal revenues would increase by about \$C 2.9 million per year as a result of increased metal recovery. Acid revenues would range from \$C -28 to +3.7 million per year. Total incremental costs to the operation would be at least \$C 3.4 million per year (1982).

The lowest cost option and the only one which offers some economic incentive in the short term appears to be increased pyrrhotite rejection. However, further research and development work is required to confirm the benefits associated with this option and to maximize nickel and byproduct recoveries. As mentioned earlier, it is also extremely important to ensure that pyrrhotite tailings are stored in a readily accessible manner, to facilitate future processing of this potential nickel resource. There is no economic incentive to proceed with any of the other options discussed above.

HUDSON BAY MINING AND SMELTING - FLIN FLON, MANITOBA

Flin Flon is an old copper-zinc operation, which relies on custom feed for about half of its overall requirements. The Flin Flon smelter operation consists of five multi-hearth roasters, one reverberatory furnace, three converters, two anode furnaces and a zinc fuming plant on the copper side, and ten multi-hearth roasters, two acid leach circuits and an electrowinning plant on the zinc side. Total capacity of the copper smelter is 65 000 tpy. The zinc plant can produce up to 70 000 tpy.

As mentioned earlier, the Flin Flon operation is one of the oldest copper smelters in the world. Because it utilizes reverberatory smelting, the operation has low energy efficiency and relatively high operating costs. Zinc production costs are also relatively high as a slag fuming plant is required to raise overall metal recovery. At present, none of the sulphur dioxide produced in the operation is captured. At full capacity utilization the copper smelter emits 167 000 tpy and the zinc plant 85 000 tpy of SO₂ per annum. Because of the low concentration of SO₂ gases, the existing smelter technology is not amenable to SO₂ control without major equipment replacements and/or substantial modifications to the present flow sheet.

Modernization/Sulphur Fixation Alternatives

Two modernization alternatives were examined for the short term. These were the zinc pressure leach process for the zinc circuit, and Inco flash smelter for the copper circuit. The figures provided here are based on a full capacity utilization production rate.

1. Zinc Pressure Leach (ZPL)

ZPL is a hydrometallurgical processing technique that produces elemental sulphur as a byproduct. The objective at Flin Flon would be to replace the multi-hearth roasters and leach circuits and integrate the ZPL process with the existing purification and electrowinning circuits. The ZPL offers the following advantages: improved zinc recoveries (98 per cent or better); lower operating costs; elimination of SO₂ emissions from the zinc plant (67 000 tpy or about 26 per cent of present emissions), and fixation of about 80 per cent of sulphide sulphur in the zinc concentrate as saleable elemental sulphur. About 20 per cent of the original sulphur in the zinc concentrate would remain with the ZPL leach residues, which would continue to be treated in the copper smelter for precious metals recovery.

Implementation of the ZPL is expected to require an investment of about \$C 43 million (1982) and yield total annual benefits of \$C 8.3 million (1982) per year. Most of this benefit is in the form of reduced operating costs. Incremental benefits of this order of magnitude would provide a pretax discounted cash flow rate of return of approximately 16 per cent.

The major constraint in implementing this technology is that further pilot scale R&D work is required to verify the feasibility of the ZPL at the Flin Flon operation. More specifically a two-stage pressure leach process needs to be developed and proven technically feasible on a "stand alone" basis. The ZPL processes in operation at Trail and Timmins are single stage "add-ons" to an existing roast leach electrowin plant.

2. Inco Copper Flash Smelter

The objective of this option would be to replace the existing roasters and reverberatory furnace with an Inco flash furnace and integrate it with existing converters and anode furnaces. Modifications would also be required to adapt the technology to handle HBMS concentrates and ZPL plant residues. An acid plant would need to be constructed to capture high strength SO₂ gases from the flash furnace.

The Inco flash offers the advantage of reducing carbonaceous fuel requirements and overall copper plant operating costs. In addition copper plant SO₂ emissions would be reduced by approximately 43 per cent or 71 000 tpy, by capturing the smelter gases as liquid SO₂ or sulphuric acid. Implementation of the Inco flash in combination with the ZPL would result in an overall reduction of SO₂ emissions of approximately 62 per cent (156 000 tpy).

Implementation of the Inco flash at Flin Flon is estimated to require a capital expenditure of \$C 127 million (1982) and yield operating cost savings of about \$C 10.8 million (1982) per year. The major drawback of the Inco flash is that it produces sulphuric acid as a byproduct. Because of the poor location of the Flin Flon smelter, the netback on acid

sales could be a very large negative number. Assuming a netback of \$C -45 (1982), overall plant revenues would decrease by almost \$C 5.5 million a year, yielding a net incremental benefit of only \$5.3 million (1982) per year under this scenario. Implementation of the Inco flash technology at Flin Flon would provide a pretax discounted cash flow rate of return of only 2 to 3 per cent.

The ZPL offers a reasonably attractive solution to improve productivity and eliminate SO₂ emissions from the zinc circuit. Because the Inco flash generates a sulphuric acid byproduct, the economic benefits associated from the copper smelter modernization are minimal at best. Initial test work indicates that copper chloride leaching technology may offer a more attractive alternative; however, considerably more development work is required on this process. This option is discussed in the chapter on new directions for research and development.

SUMMARY OF IMPACTS OF MODERNIZATION

Impacts of the modernization/sulphur fixation alternatives examined in this chapter are summarized in Table 5.1. Capital and operating costs are in 1982 dollars. Metal and acid revenues are also expressed in 1982 dollars, but are based on predicted prices for the early 1990s. Netbacks on acid sales vary from \$C -15 to \$C +20 per tonne for a Sudbury area location to \$C -45 to \$C -50 per tonne for a Flin Flon or Thompson location respectively.

Preliminary estimates on the requirements for operating labour are also provided. For integrated operations and those options which impact on ore requirements, the estimates also include the changes in labour requirements at both the mining and milling stages. It should also be noted that some of the incremental benefits (operating costs and labour requirements) may be high when compared with a present day "base case", due to "cost cutting" measures recently implemented at some smelter sites, particularly Inco Sudbury.

In general, the modernization/sulphur fixation alternatives, which appear technically feasible in the short term, do not offer very attractive economic solutions to the industry's economic and environmental problems, though there are a few exceptions. For those older operations, the benefits from modernization are quite limited and do not justify the capital expenditures involved. For more modern facilities, sulphur fixation programs would impose a significant cost burden on the operation. The unattractiveness of these technologies is due, in large measure, to the fact that sulphuric acid is produced as a byproduct.

The exceptions, to the above general conclusion, are the modified ZPL for HBMS and possibly pyrrhotite rejection for Falconbridge, neither of which produce byproduct sulphuric acid. In both cases, there appears to be scope to achieve productivity improvements and an adequate return on investment, while achieving significant reductions in SO₂ emissions.

TABLE 6.1
Summary of Incremental Benefits or Losses

Company	Modernization Alternative	Range of Incremental Benefits or Losses						Assumed Production Rate tpy		
		Capital Costs 106\$C/yr	Operating Costs 106\$C/yr	Metal Revenues 106\$C/yr	Acid Revenues 106\$C/yr	Total Benefits or Losses 106\$/C/yr	Labour Impacts	Acid ⁴ Pro-duction tpy,**	SO ₂ Emissions tpy	Reduction in SO ₂ Emissions tpy
Inco Sudbury	(1) RRS Process	430	-20	0	-10 to +14	+10 to +34	-272	665 000	320 000	450 000
	(2) Acid from copper converters	120	+5.5	0	-4.2 to +5.6	-9.7 to 1	+47	280 000	590 000	180 000
	(3) Combined (1) & (2)	550	-14.5	0	-14.2 to +19.6	+3 to +34.1	-225	945 000	140 000	630 000
Falconbridge	(1) Po rejection*	12	+3.0	+4.25	—	+1.2	+54	—	114 000	42 000
	(2) Acid from converters	70	+3.3	0	-2.2 to +3.0	-5.7 to -0.3	+28	144 000	60 000	96 000
	(3) Acid from Regenerative scrubbers	51	+13.7	0	-3.2 to +4.3	-16.9 to -9.4	+120	214 000	16 000	140 000
Noranda Horne	(4) RRS	67	+10.0	+2.9	-2.8 to +3.7	-9.9 to -3.4	+70	185 000	34 000	122 000
	(1) Acid from reactor	80	+5.2	0	-5.5 to +7.4	-10.7 to +2.2	+44	370 000	320 000	240 000
	(2) Acid from reactor and converters	115-150	+7.5	0	-8.3 to +11.0	-15.8 to +3.5	+64	550 000	202 000	358 000
Inco Thompson	(1) Acid from roasters	46	+4.3	0	-8.0	-12.3	+37	159 000	120 000	104 000
	(2) Acid from roasters and converters	95	+7.9	0	-13.3	-21.2	+67	265 000	51 000	174 000
	(3) RRS process	125	+7.7	+0.5	-15.3	-22.5	+89	306 000	29 000	196 000
HBNS	(1) ZPL process	43	-7.5	-0.5	+1.32	+8.3	-70	0	185 000	67 000
	(2) Inco flash	127	-10.8	0	-5.5	+5.3	-54	122 000	181 000	71 000
	(3) Combined (1) & (2)	170	-18.3	-0.5	-4.8	+13.0	-124	136 000	96 000	65 000

Source: Cammet, Energy, Mines and Resources Canada.

1 Incremental metal revenues are related to increased or decreased byproduct credits which are dependent on concentrate requirements and metal recoveries in the various processes. Prices used are predicted prices in 1990 expressed in 1982 C\$: Cu - \$1.06/lb; Co - \$.60/lb; Platinum Group Metals (P.M's) - \$380/oz; Ag - \$13/oz; Au - \$685/oz; Zn - \$0.56/lb; Ni - \$3.62/lb; ICS = .8 U.S. 2 This is a sulphur revenue based on \$40/tonne netback. 3 Operating labour in person years per year. 4 Total sulphuric acid production associated with these options could approach 2 026 000 tonnes per year. Maximum incremental production could be 1.6-1.7 million tpy if allowance is made for the phase out of existing IOPR acid production at Inco Sudbury. Actual incremental acid production volumes will be determined by actual metal production rates at each operation.

5 The increased revenue shown here is at the expense of metal losses resulting from the po rejection process which has a gross value of about \$24.5 million (1982) and which Falconbridge would normally recover if Po rejection was not implemented (see p. 18).
* Po - pyrrhotite. ** tpy - tonnes per year.

CHAPTER VII

CORPORATE FINANCIAL CONSIDERATIONS

This chapter provides an insight into the financial capacity of Inco, Falconbridge, Noranda and HBMS to undertake the modernization/sulphur fixation programs discussed in the previous chapter. The discussion begins with a brief overview and analysis of the consolidated financial data of the above four companies and then proceeds to an assessment of the priorities of each individual corporation, from a financial standpoint, over the next 10 to 15 years.

OVERVIEW

The recent severe recession had a dramatic impact on the financial structure of Canada's major nickel and copper producers. Corporate earnings and cashflows fell sharply. Over the last three years the group recorded about \$1 billion in aggregate net losses. Because of previous commitments, capital expenditures for the group remained high, approximately \$1.9 billion during 1981 and 1982. Unable to meet cash needs from internal sources, companies turned to external capital markets. In 1981 and 1982, borrowing amounted to about \$1.2 billion, constituting nearly a 50 per cent increase in debt. Despite new equity issues totalling \$641 million, equity declined by \$76 million. Overall, the financial position of the group deteriorated significantly as debt-to-equity ratios increased from 33:67 in 1980 to 43:57 in 1982. Moreover, levels of indebtedness for many of the companies began to approach practical borrowing limits and covenants established with their respective bankers.

Much of the group's increased debt load was short term with high floating rates. During the recessionary period, the ability of the firms to service their debt load fell to dangerously low levels, as evidenced by sharply falling interest coverage ratios, which turned negative in 1982.

Even though the group recorded an aggregate net loss of \$276 million in 1983, the situation has eased somewhat from the 1982 crisis. Each firm has managed to reduce costs significantly, and all have dramatically curtailed capital spending to conserve cash. Furthermore, because of lower rates of interest, the burden of floating-rate debt has lessened. Nonetheless the group as a whole, remains seriously over-levered. In order to rectify this situation a large portion of discretionary cash flow will have to be directed to debt reduction for at least the next several years.

Mining has always been a cyclical industry with its attendant risks. However, because of the structural changes in world metal markets, mining industries in industrialized countries now appear to have a higher degree of operating risk than before, as witnessed by the heavy losses recorded during the recent recession. On top of this, additional financial risks have emerged with the possibility of a return to high and volatile

interest rates. Consequently, a traditional debt-to-equity ratio of 35:65 can no longer be considered a desirable target. In the increasingly harsh international marketplace, a longer term debt-to-equity ratio of 30:70 may now be a more appropriate target. It is estimated that at least \$1.2 billion in new equity in the form of retained earnings or new stock issues would be required to achieve this target ratio.

Given expectations of slow growth in metal demand and price recovery over the remainder of the decade, earnings are not expected to recover quickly. Moreover, the ability of firms to sell more stock could be quite restricted. Recapitalization and restructuring of balance sheets will be a high priority for most companies. Consequently, funds available for new productive investments could be quite limited. In addition, because of existing large loss-carryforwards, the group will not likely be in a fully taxable position for several years. These factors, in combination with other pressing priorities, such as the need to improve mine productivity and to rebuild ore reserves, suggest that most firms will not be in a position to proceed with major smelter modernization/sulphur fixation programs much before the late 1980s or early 1990s.

INCO

Inco has recorded substantial net losses over the last three years, totalling some \$908 million. These huge losses are, in large measure, the result of several unsuccessful ventures around the world; however, operating losses have also been substantial. To conserve cash, Inco cut back capital expenditures on continuing operations in 1982 from a planned \$152.2 million to an actual \$95.3 million and deferred development of the Thompson open pit mine by one year. Despite these efforts the company reported internal cash shortfalls of \$55 million in 1982 and \$57 million in 1983.

Notwithstanding its recent poor performance, the company was able to reduce its debt by almost \$130 million in 1982 and by another \$29 million in 1983. At present, Inco has significant unused credit facilities.

Capital Structure, December 31, 1983

	<u>\$ millions</u>	<u>Per cent</u>
Debt	1 174	42
Deferred taxes	241	9
Preferred shares	335	12
Common equity	1 027	37
	<u>2 777</u>	<u>100</u>

The company's restrictive covenants for credit lines specify a maximum debt-to-equity ratio of 50:50 after 1984. This ratio stood at 47:53 at December 31, 1983. Inco had available unutilized credit facilities of \$425 million at December 31, 1983. However, it appears that Inco will not have serious problems keeping within its borrowing limit.

Inco's interest coverage has declined to well below normal requirements as a result of poor earnings over the last two years. The ratio stood at 3.91 in 1980, but turned negative in 1982 and 1983 because of very large operating losses. The company's ability to continue to raise debt at reasonable cost to meet its financial requirements has been lessened somewhat by reductions in bond and commercial paper ratings, most recently in January 1984.

The company is not likely to quickly regain its former bond ratings in the A to A+ range. Inco will have to demonstrate that steps have been taken to permanently restore its prior earnings performance and this may entail, for instance, improving its interest coverage and maintaining it at a 3.0 to 3.5 times level for a period of years. Although the maximum debt-to-equity ratio has been set by creditors at 50:50, a healthy longer term target for debt equity would probably be somewhat more conservative and possibly in the 30:70 range.

Inco raised \$72.4 million in May 1982 through the sale of 6.9 million shares with warrants in Europe, the United States and Canada. Another issue of 6 million shares realizing \$52.1 million was made in Canada, United State and Europe in November 1982 and one of 6.6 million shares netting \$80.4 million was made in the United States in March 1983. The proceeds of these issues were mainly used to reduce short-term borrowings. It is expected that all outstanding warrants will be exercised at \$16.00 (Cdn.) in mid-1985, adding \$56 million (Cdn) in cash.

The company's dividend policy is to pay out about one third of reported earnings under normal conditions. However, the quarter-to-quarter decision to continue payment of dividends will depend on business results and cash needs. Common stock dividends were reduced and maintained at 5 cents per quarter effective the 4th quarter of 1981, down from 18 cents, which had been paid since the 2nd quarter of 1980. Inco must pay dividends even during periods of losses, in order to keep its shares attractive to institutional investors.

Outlook

The company's longer term profitability will be dependent to a significant extent on its ability to achieve productivity gains and maintain a lean cost structure in the face of continued strong competition and a relatively weak nickel market. A key priority for the company will be to implement major productivity improvement programs at its Sudbury and Thompson mining operations. In addition, Inco must work to reduce its heavy debt load to provide greater flexibility in its operation.

Over the next five years Inco's cash commitments, including scheduled debt repayments, are expected to average approximately \$450 million per annum. This is a very substantial commitment even for a company the size of Inco. These projections are based on the assumption that the company will not undertake any major capital expansions other than the development of the Thompson open-pit mine, for which a provision of \$45 million in 1984 and 1985 has been made.

If nickel prices do not improve materially over the current depressed situation, Inco's financial position will continue to deteriorate. Within a few short years, the company could face serious financial difficulties. However, under a moderate recovery scenario, as outlined in Chapter II, Inco is expected to generate a positive cash flow from operations in 1985, and return to profitable operation in 1986. However, restructuring of the company's balance sheet is not expected to be completed much before 1988. In addition, because of the company's large loss-carryforwards Inco will not be in a position to take full advantage of existing tax incentives for several years to come. Based on these financial projections, it is unlikely that Inco will be able to proceed on its own with a major smelter modernization program until sometime in the late 1980s.

FALCONBRIDGE

Like Inco, Falconbridge has also suffered heavy financial losses, almost \$110 million over the last three years. The company reported a negative cash flow from operations of \$91 million in 1982 but managed to generate a positive cash flow in 1983 of about \$14 million.

Capital Structure, December 31, 1983

	<u>\$ millions</u>	<u>Per Cent</u>
Debt	485	46
Deferred taxes	52	5
Common equity	508	49
	<u>1 045</u>	<u>100</u>

Up until 1980 Falconbridge was able to finance cash requirements primarily from internally generated funds. However, in 1981 the company borrowed \$171.0 million in long-term debt as a precautionary measure against a down cycle to ensure that adequate funds were available to finance operating and capital expenditures. This decision was influenced by declining profitability, rising capital expenditures, inventory buildups, and increases in costs due to inflation. Because of recent heavy losses, a \$103 million equity issue was made in February 1983 to shore up the capital structure of the company.

The company's debt covenants specify 45 per cent as a maximum limit for consolidated debt as a percentage of certain consolidated net tangible assets. At present, Falconbridge has credit facilities up to \$265 million. Of this amount, \$80 million was unutilized at December 1983. In addition other lines of credit of \$125 million in Canadian and \$20 million in U.S. dollars are available and being used mainly to discount notes and receivables. However, use of these facilities is extremely limited by the debt covenants referred to above. Indeed, the company raised another \$15.8 million in a new equity issue on January 18, 1984 to meet sinking fund payments.

The company's interest coverage has declined to well below normal requirements as a result of poor earnings over the last three years. The ratio stood at 7.34 times in 1979, but fell to 5.23 times in 1980 and 0.78 times in 1981, but has been negative since then because of operating losses.

The company is not likely to be in a position to borrow from debt markets until it has demonstrated that steps have been taken to permanently regain its prior earnings performance and this may entail, for instance, improving its interest coverage and maintaining it at a 3.0 to 3.5 times level for a period of years. Furthermore, although the maximum consolidated debt-tangible-assets ratio has been set by creditors at 45 per cent, a healthy longer term target in terms of a debt-to-equity ratio would probably be somewhat more conservative and possibly in the 30:70 area.

Outlook

Falconbridge has taken strong measures to streamline its operation and enhance its competitive position. However, the company can no longer afford to postpone necessary expenditures, on-property exploration and mine development work. The first priority of the company therefore must be to rebuild its mining capacity so that it can maintain and perhaps increase its production if and when the nickel market recovers. Secondly, discretionary cash flow must be used to restructure the company's balance sheet in order to achieve a healthier debt equity ratio.

The company's cash commitments over the next five years total approximately \$130 to \$145 million per annum including approximately \$30 million per year for maintenance of existing operations. These projections are based on the assumption that the company will not undertake any major capital expansions. Scheduled debt repayments do not exceed \$20 million for 1984 and 1985, however \$240 million comes due in 1986. The company could face additional cash obligations, if creditors accelerate the debt repayment requirements on outstanding loans to Falconbridge's Dominicana subsidiary.

Based on the nickel market forecast in Chapter II, Falconbridge should turn a small profit in 1984 and continue to show improvements through the balance of the 1980s. However, given the company's cash commitments, it is unlikely that it will regain its former financial vitality until sometime in the mid to late 1980s. The sulphur fixation alternatives examined in the previous chapter are not significant in terms of Falconbridge's overall capital structure. However, each alternative would result in increased operating costs, which would undermine the company's campaign to improve productivity and financial stability.

NORANDA

Noranda is much more difficult to assess because it is so widely diversified. The company is engaged directly and indirectly, through subsidiaries and affiliates in mining, forest products and manufacturing, with total assets of about \$5 billion. By 1986, the company expects profit distribution to be 40 per cent from forest products, 33 per cent from metals and minerals and 20 per cent from manufacturing.

Noranda experienced an operating loss of \$140 million in 1982. This was the company's first loss ever. In comparison, the 1983 loss was cut to \$5.6 million. To minimize losses a number of mining operations were closed temporarily or permanently in 1982 or 1983 including Gaspé, Lyon Lake, Mattabi, Brenda, Goldstream, Granisle, Bell and Boss Mountain. Operating rates in smelters, manufacturing facilities and forest product operations were substantially reduced. At the end of 1982 Noranda had 10 000 fewer employees compared with year-end 1981.

Although operations in 1982 generated only \$114 million in cash, Noranda continued major expenditures on fixed assets amounting to \$660 million in 1982 and borrowed \$900 million to meet its overall cash shortfall. In 1983, Noranda's cash flow from operations improved by 50 per cent to \$170 million; capital spending was reduced to \$359 million.

In 1980, Noranda had very little debt in its capital structure, but by 1982 the situation had changed dramatically due to expensive modernization programs and the acquisition of MacMillan Bloedel Limited. At December 31, 1982 its debt load amounted to \$1.9 billion, of which approximately \$1.3 billion was at variable rates.

Capital Structure, December 31, 1982

	<u>\$ millions</u>	<u>Per cent</u>
Debt	1 949	39
Deferred taxes	364	7
Preferred shares	358	7
Common equity	2 348	47
	<u>5 019</u>	<u>100</u>

Currently, Noranda's debt-to-equity ratio is 42:58 compared with 28:72 in 1980. The company's interest coverage ratio also deteriorated dramatically over this period.

Since a number of major projects were completed in 1982 the deferral of interest charges through capitalization will decrease and interest expense on the income statement will increase substantially. This will be partially offset by lower effective rates of interest on its large portion of variable-rate debt. Scheduled long-term debt repayments for 1984 and 1985 are \$274 million and \$557 million, respectively, which will limit cash available for other purposes.

Due to the "Noranda Group's" instability of earnings, Noranda's debentures were downgraded in 1978 to A from A+ and in 1982 to B++. The poor performance in 1982 and expected poor cashflows in 1983 may result in future downgradings.

The company's last major share issue was in 1981 as part payment for Noranda's 49 per cent interest in MacMillan Bloedel. Noranda also raised \$500 million in 1981 by selling to Brascade Resources Inc. 12.5

million treasury shares as part of the Brascade-Noranda takeover agreement. Dividends were cut in 1982 to an annual rate of \$.50 per share, down from \$1.40 in 1981. Dividends in 1983 and 1984 are expected to remain unchanged at \$.50 per share. Over the last ten years Noranda has paid out about 40 per cent of earnings as dividends.

Noranda has been involved in major modernization and expansion programs since 1980. Major expenditures in mining and metallurgy include the Gallen, Goldstream and Grey Eagle mines (\$100 million); the Horne smelter oxygen plant (\$80 million); and the Canadian Electrolytic Zinc roaster and acid plant (\$65 million). In forest products, substantial expansion and modernization expenses were incurred by Northwood Pulp (\$375 million); and Maclarens newsprint mill modernization (\$28 million) and pulp mill environment improvement program (\$72 million). Major capital commitments by the manufacturing groups include Noranda Aluminium Inc.'s third potline at Madrid, Missouri (\$280 million); and, Canada Wire and Cable Limited's new continuous cast rod mill (\$22 million). Over \$600 million was spent on capital projects in each of 1981 and 1982. However, capital spending in 1983 fell sharply to \$359 million, reflecting the company's efforts to conserve cash.

Regarding Noranda's Beta division, comprising the Horne, Gaspé and Canadian Copper Refineries (CCR) operations, profitability has been declining steadily over the last several years. This has been due to declining concentrate feed from local sources and unfavourable low treatment charges. For the Horne smelter, no significant improvement is expected for some time. Feed from local sources is expected to decline further and additional transportation costs will be a major factor in the Horne's ability to compete for concentrate from British Columbia and possibly offshore sources. Because treatment and refining charges (TC/RC's) will continue to be under considerable pressure, the Horne will likely be no more than a marginal operation, at best, for at least the balance of this decade. The Gaspé is in even worse financial circumstances and consequently in a much more vulnerable position than the Horne smelter.

Outlook

Noranda has taken strong measures to conserve cash. It has trimmed staff, increased productivity and reduced capital spending programs. The company has been able to minimize inventory build-ups by curtailing production. The company also benefitted from lower interest rates in 1983. In the short term, because metal price increases will be sluggish, a number of operations will remain closed or operate at only partial capacity.

Noranda will not be undertaking major discretionary capital spending programs on existing facilities in the next few years. Work will continue on precious metal projects, particularly the Hemlo gold deposit, since these are the only projects offering good returns on investment in Noranda's overall mining operations. Debt reduction will also be a high priority for the Noranda Group of companies for the next several years.

As mentioned in Chapter VI the cost of the pollution abatement program for the Horne smelter is estimated at between \$80 to 150 million (1982). This amount is not large in comparison with Noranda's overall capital spending budget in recent years. However, because this project is expected to have a low or possibly negative incremental rate of return, it will be difficult to compete internally with other more attractive capital projects within the Noranda Group. Since the Horne smelter faces a highly uncertain concentrate supply picture, it is possible that the company may choose to meet any required reductions in SO₂ emissions simply through a cutback in production. A similar scenario is also quite possible and perhaps even more likely in the case of the Gaspé smelter.

HUDSON BAY MINING AND SMELTING (HBMS)

As a result of a major reorganization, HBMS is now completely controlled by the Inspiration Resources Corporation of New York, which owns all of the outstanding common shares. HBMS "special" shares trade on the Toronto Stock Exchange, and while these shares do not carry voting rights in HMBS, each special share has a vote equivalent to one Inspiration common share. Eventually the special shares will have to be exchanged for Inspiration common shares. Minerals and Resources Corporation Limited, (Minorco) of Bermuda, holds a 60 per cent equity interest and a 46 per cent voting interest in Inspiration. Minorco is the holding company for the North American interests of several major mining companies, including Anglo American Corporation of South Africa Ltd. and De Beers Consolidated Mines Ltd.

Like many other mining companies HBMS has found itself in a cost-price squeeze, which has persisted for several years. The effect of this squeeze is illustrated in the following table, which sets out the operating income over the 1978-1983 period.

HBMS Earnings Performance*
(\$millions)

<u>Year</u>	<u>Operating Income (Loss)</u>
1983	(4.7)
1982	(32.1)
1981	(5.0)
1980	25.4
1979	16.2
1978	(1.7)

* Restated to reflect the effects of the reorganization.

During 1982 HBMS experienced a negative cashflow from operations of \$27.4 million in comparison with positive cashflows of \$25.1 million in 1981 and \$52.6 million in 1980. Because of favourable zinc prices, lower production costs and capital deferrals, 1983 should see a somewhat better performance. Indeed, cash flow from operations of \$18.8 million has been recorded for the year 1983.

While cashflows from operations have been weak in recent years, the company has been able to maintain a reasonably sound capital structure partly as a result of new equity issues and asset sales. In 1983, HBMS raised \$86.1 million from the sale of special shares and warrants. The transfer of the Island Falls power plant to the Province of Saskatchewan and the reorganization of its petroleum interests also provided HBMS additional working capital of \$76.6 million over 1981 and 1982. However, it is unlikely that any additional cash can be raised through asset sales in the future.

Capital Structure December 31, 1983

	<u>\$ millions</u>	<u>Per cent</u>
Long-term debt	61.4	16
Deferred taxes	47.0	12
Equity	270.7	72
	<u>379.1</u>	<u>100</u>

Interest expense on long-term debt was \$8.2 million in 1982 and \$9.3 million in 1983. Scheduled debt repayment is no more than \$6.5 million per year to 1988. Therefore, debt servicing should not prove a serious problem to the company over the next few years.

All of HBMS' common shares are held by Inspiration Resources. It is difficult to evaluate the dividend policy of the firm both because of an inconsistent history and because of its new status as a subsidiary. Future dividend policy may depend upon the cash needs of Inspiration. The parent company is more heavily levered than HBMS and several other subsidiaries such as Inspiration Consolidated Copper Company and Inspiration Coal Inc. are still experiencing serious losses, so cash may be required from HBMS.

Outlook

HBMS has been able to maintain a fairly good financial position, despite the severe economic recession. The firm has a good equity base, has access to debt capital, in the form of unused lines of credit and has no pressing liquidity problems. Unlike many other mining companies, HBMS will not have to continue the process of financial retrenchment since it has re-established a sound capital structure.

Nevertheless, Flin Flon is a moderate cost operation with an uncertain supply picture. It is not well situated to compete for copper concentrates from British Columbia or offshore markets. At today's prices for copper, zinc and precious metals, the company is just generating enough cash flow to cover its direct operating costs and limited exploration and mine development work.

Over the longer term, HBMS faces several major challenges. First, due to its location, it is vital that the company develop and maintain significant sources of smelter feed close to Flin Flon. This will require the firm to rebuild reserves, maintain and expand existing mine

capacity and replace depleted mines. Consequently, the first priority of the firm must be to establish a reserve position consistent with the long-term operation of the company, to increase its overall cost competitiveness and to reduce its dependency on custom feed. This will be an expensive endeavour. To accomplish this goal, a mine exploration and development program costing between \$250 to 300 million (in 1983 constant dollars) over the next seven to eight years would be required. This is a very large commitment for a company with a total existing capitalization of approximately \$379 million.

Based on current metal price forecasts and projections of HBMS's costs it does not appear that the required capital expenditure program can be financed from internal sources. Rather, it is more likely that a significant proportion of the cash requirement would have to be raised from external sources. In this regard, HBMS's ability to raise external financing could be influenced by the overall needs and objectives of the Inspiration Resources group of companies.

The second priority of the company, once security of reasonably priced concentrate supplies has been assured, should be a major modernization of its processing operations. The estimated capital cost of this program is approximately \$170 million (1982 constant dollars). Although further R&D work is required, the major constraint with respect to modernization is financial and not technical in nature. It is clear that the firm cannot afford to rebuild and maintain its reserve position and modernize its processing operations concurrently. Indeed, a major modernization program of the zinc plant and copper smelter should not be considered until supporting ore reserves have been established. It is expected to take several years for HBMS to rebuild its reserves. Consequently, it is unlikely that the company will be in a position to modernize its smelting operations much before the early 1990s.

SUMMARY COMMENT

Canada's major nickel and copper firms will not be in a strong position to embark on major smelter improvement programs much before the late 1980s and in some cases the early 1990s. By this time, the financial circumstances and internal cash flow generation capability of individual companies are expected to improve significantly.

However, the analysis also suggests that if major reductions in SO₂ emissions are required from nonferrous smelters before the early 1990s, some form of government assistance may need to be provided, particularly if major potential economic dislocations are to be minimized. Given the taxable position and balance sheet problems of many of the companies, it would appear that, under these circumstances, consideration would have to be given to various incentive mechanisms that would assist in raising equity financing (e.g., term preferred shares, special flow through shares, etc.), in addition to other traditional instruments such as cash grants, guaranteed loans, etc.

CHAPTER VIII

NEW DIRECTIONS FOR RESEARCH AND DEVELOPMENT

Very few of the modernization and sulphur fixation alternatives that are technologically feasible in the short term offer attractive solutions to the problems confronting Canada's nickel and copper smelters today. Recognizing this, the scope of the technological profiles undertaken for each plant was broadened to include identification of longer term, higher risk technologies, which could perhaps offer more attractive alternatives. This work was not limited to smelter processes alone. Rather, smelter modernization was considered as only one element or part of a total modernization concept, which for most operations could encompass the development of new or modified technologies, to reduce milling and/or refining costs, as well as having a potentially beneficial effect on smelting costs and SO₂ control.

A number of promising new and/or modified technologies have been identified. Considerable work is required to develop and demonstrate the technical and commercial viability of these processes. However, if proven successful, these new technologies could offer a much more cost-effective route to achieve the twin objectives of increased productivity and pollution control.

Some of the new directions, into which a more concerted R&D effort should be channelled, are discussed here. This is followed by a plant by plant discussion of the specific R&D projects that could be considered to improve productivity and/or to make pollution control more affordable.

NEW DIRECTIONS

Improved Pyrrhotite Rejection for Nickel

Implementation of more advanced pyrrhotite rejection is a very economically attractive method for reducing nickel smelter SO₂ emissions and smelter operating costs. It is desirable therefore to thoroughly evaluate improved pyrrhotite rejection processes to determine the incentive for implementation by accurately comparing the downstream economic and environmental benefits against the increased mining-milling costs, and possibly decreased byproduct credits, resulting from decreased recovery of metal values from the ore. The objective of a R&D program in this field would be to develop beneficiation techniques that will minimize metal losses during pyrrhotite rejection while producing high-grade nickel and copper concentrates and giving efficient nickel-copper separation.

Continuous Converting Processes for Copper and Nickel

Continuous converting technology can offer benefits in terms of energy savings, productivity improvements, greater SO₂ containment and a cleaner work environment. Problems related to impurity elimination,

particularly in copper, and metal and byproduct recovery have hindered development work on this technology. If these problems can be overcome, continuous converting can be a much more economically attractive alternative than hooding of converters to capture SO₂. Achievement of this goal requires continuing development of a much more sophisticated data base on the chemical and physical properties of molten slag-matte-metal systems, and the effect of gas phase composition on their equilibria composition.

For copper, the development of better methods to reject undesirable impurities such as arsenic, antimony and bismuth, and to reduce copper and precious metal losses will enhance the viability and flexibility of continuous processing technologies. The recovery of molybdenum and cobalt should also be investigated in cases where significant quantities of these elements are present in the concentrate.

For continuous nickel processes, the major effort should be directed towards improving cobalt recovery as well as nickel and copper, while minimizing problems related to impurities. Because of the very high iron content in nickel concentrates, very small reductions in the metals content of the slag can result in significant increases in recovery.

Copper Chloride Leach Process

Hydrometallurgical processes do not produce SO₂ and therefore have virtually no environmental constraints related to SO₂ emissions, or production constraints related to sulphuric acid marketability. Some of the processes can also convert most of the sulfides in base-metal concentrates to elemental sulphur, which can be recovered and sold if markets are available, or stored indefinitely with no detrimental environmental effects. Elemental sulphur is also a much higher value commodity than sulphuric acid and can be shipped at least three times as far for the same cost per unit of sulphur. Sulphur producing processes therefore could be ideal for inland base-metal smelters located far from acid markets such as HBMS. Hydrometallurgical processes also offer a further advantage, in that size of operation is not as critical in achieving economies of scale, and they are generally more adaptable to the treatment of complex concentrates. They can however have other problems related to precious metals recovery, energy requirements, iron removal and the control of aqueous effluents.

For copper the most desirable processes are those that convert sulfides in the concentrates directly to elemental sulphur, while maintaining copper and iron in their lower valence states. This minimizes the capital and energy costs of the process, and can be accomplished effectively only if the process is carried out in chloride media. Iron rejection is also facilitated in chloride media and a saleable iron product can be produced if economics so warrant. However precious metals recovery and the production of high purity cathode copper can be a problem. Pilot scale development is required to verify methods for silver removal and recovery from chloride leach liquors and to facilitate the production of high purity cathode copper; to optimize the design of diaphragm electrolytic cells for copper chloride electrowinning, to recover gold, sulphur and molybdenum from leach residues, and to remove iron from the system in the most cost effective manner.

Copper Refining Technology

Further research and development work is required to develop improved electrorefining techniques in order to reduce labour, inventory and anode recycle costs, while minimizing problems related to copper quality. More advanced techniques that enable refining of anodes with relatively high impurity levels could have significant implications for smelter operations, particularly those treating complex concentrates.

Nickel Smelting Technology

There is little doubt that the RRS process offers the best short-term compromise between minimizing technological risk and maximizing environmental benefit. Economic benefits, however, are marginal at best. Based on commercially proven flash smelter technology, a flash smelting, continuous converting process for nickel may offer greater long-term potential for maximizing both economic and environmental benefits. A comprehensive R&D program should be initiated to determine the technical feasibility of such a process, with special emphasis on obtaining high metal recoveries while minimizing energy requirements and costs for slag cleaning.

Sulphuric Acid Plant Technologies

A concentrated R&D effort is required to reduce capital and operating costs associated with containment of SO₂ gases via the production of sulphuric acid. This should include the development of more efficient and less costly gas cleaning and cooling techniques and new acid plant technologies employing fluid bed catalytic converters to facilitate the conversion of high strength (25 per cent) SO₂ gases. The latter could be particularly relevant to the Inco flash furnace and Noranda reactor process technologies, and could significantly reduce both capital and operating costs associated with SO₂ control.

Alternate Sulphur Fixation Technologies

To alleviate the problems associated with the transportation and marketing of sulphuric acid, it is desirable to investigate other sulphur fixation alternatives, particularly those that produce much higher value byproducts, such as fertilizers or elemental sulfur.

1) Fertilizer Technologies

It is possible to import phosphate rock and convert it into phosphoric acid or phosphatic fertilizers using smelter sulphuric acid. This is being done now by several Canadian companies to the point that the Canadian market is largely satisfied. However, over the last five years or so, U.S. integrated phosphate fertilizer producers have made significant inroads into the Canadian market. This market penetration reflects the capital and operating cost advantages enjoyed by U.S. integrated producers over Canadian competition. In particular, Canadian producers suffer the disadvantage associated with the high cost of imported phosphate rock.

World demand for phosphate fertilizers is expected to grow at an average rate of 3.5 per cent per year to the year 2000. This, coupled with recent renewed interest in phosphate rock deposits in northwest Ontario, suggests that new phosphatic fertilizer production in Canada, using indigenous resources, is a distinct possibility.

In addition there are new technologies that offer the potential of altering the economics of phosphatic fertilizer production in favour of Canada. For example, a study carried out by Kilborn Limited in 1981-82 evaluated a process for the coproduction of potassium phosphate and high quality phosphoric acid. The results were encouraging based on limited pilot plant data. If these new technologies prove out and if the economics are favourable, new fertilizer production in Canada based on indigenous resources could provide a major outlet for incremental smelter abatement acid.

2) SO₂ to Elemental Sulphur

Investigations are also warranted on the development of less energy intensive processes for producing sulphur from SO₂. These could include the use of pyrrhotite as a reductant, or a source of H₂S for the production of Claus plant sulphur.

Pyrrhotite Processing

For the long term, it is desirable to develop a process for treating pyrrhotite, particularly with the introduction of the pyrrhotite rejection process and the possible extended use of it. A comprehensive R&D program is required to develop a process that has the capability to recover nickel and associated valuable metals from pyrrhotite, while converting sulphides directly to elemental sulphur. A process employing "chloride metallurgy", either aqueous or dry, appears to offer the most promise as a technically and economically viable process.

PLANT BY PLANT ASSESSMENT

Table 8.1 summarizes the major R&D projects on a plant-by-plant basis and provides an estimate of the total expenditure involved in developing and demonstrating these new technologies. A brief discussion of the projects that could be undertaken by each company is provided below.

Inco

1. Sudbury

Based on previous testwork, Inco is confident that the RRS (IORP) process, compared with alternative technologies such as nickel flash smelting, continuous converting, offers the best compromise between energy efficiency, metals recovery and SO₂ capture at least in the short term. The RRS also offers significant capital cost savings in comparison with a new smelter since implementation will make use of existing roasters located at the iron ore recovery plant.

The major shortcoming of the RRS is that the economic benefits realized from its implementation are meagre and do not justify the capital expenditure involved. Inco's first priority with respect to the Copper Cliff operation should be to examine ways and means to reduce the capital costs associated with the RRS process, while striving to maintain economic benefits at current levels.

Currently, Inco's major efforts are centred on determining the potential for incorporating the existing converters and specially equipped reverbs into the RRS flowsheet to reduce its capital cost. Other ongoing studies which Inco are pursuing include the development of lower cost transport and storage systems for concentrates, roaster calcine and rejected pyrrhotite.

Recent improvements in the performance of the existing nickel converters have convinced Inco of their suitability for the RRS process. Major improvements in conventional reverberatory furnace smelting, brought about by installation of roof-mounted oxy-fuel burners have stimulated interest in their potential for reduction smelting. Inco will be carrying out work during 1984 that will lead to a decision by year-end as to whether or not it should pursue commercial-scale testing of the RRS process using these specially equipped reverberatory furnaces. It is estimated that these additional investigations including engineering, plant modifications and trials would take two full years (i.e., 1985 and 1986). The cost of this development program could approach \$C 15 million.

Based on a 5 to 6 year construction schedule, full scale operation of the RRS process at Sudbury, incorporating existing or modified reverberatory furnaces and converters, could not be expected much before 1992.

Should it turn out that only the existing converters and converter aisle could be incorporated into the RRS process, it is expected that 1.5 years would be required to complete the engineering of suitably sized electric furnaces for installation in the vicinity of the existing reverb units. Construction of new electric furnaces and infrastructure within an operating smelter would face significant scheduling and access limitations that would not be encountered in the original concept to construct new smelting and converter facilities east of the existing smelter site. Completion of this alternative strategy therefore would also not be expected much before 1992.

From the original \$C 430 million (1982) capital cost estimate, savings associated with lower cost transport-storage systems and utilization of existing converter and reverberatory smelting units could approach \$C 200 million (1982). Should new electric furnaces be required, this saving would be reduced to between \$C 100 to 150 million (1982).

Another high priority objective at Sudbury is to improve copper smelting technology. A comprehensive R&D program is required to determine the technical feasibility of a flash smelting, continuous converting process for copper with emphasis on maximizing copper recovery while minimizing costs associated with slag cleaning, including byproduct nickel recovery. This program is estimated to cost \$C 25 million over a 5-year period.

Another high priority for Inco will be to reduce the metal content of rejected pyrrhotite, to increase the grade of nickel concentrate and to improve copper-nickel separation. Further testwork is estimated to cost \$10 million over a 3- to 5-year time period.

Research and development work at Inco should also focus on reducing copper refining costs through the introduction of automated equipment. Nickel refining processes at Sudbury and Thompson should also continue to be examined to explore ways of improving productivity.

2. Thompson

At Thompson, the first priority must be to develop improved pyrrhotite rejection techniques to achieve the targetted 50 per cent sulphur to tailings objective, while minimizing metal losses. Further development work should then be pursued to define the ultimate sulphur rejection potential, as this potentially represents the lowest cost means of lowering SO₂ emissions.

A concerted effort is also required to develop new technologies for SO₂ capture that are less costly than sulphuric acid production, with its attendant large potential negative netbacks. SO₂ conversion to fertilizers or elemental sulphur are two candidates. Neutralization is not an option. Cost will be as high or higher than the negative netbacks on acid sales. Total cost of the R&D projects for Inco at Thompson could approach \$10 million over a 3- to 5-year period.

Hudson Bay Mining and Smelting

Hydrometallurgical technologies offer the most promise for HBMS to effect major improvements in smelter productivity and pollution control. Not only would these processes result in 100 per cent containment of sulphur in concentrate but the potential economic benefits associated with their implementation could more than justify the capital expenditures involved. Hydrometallurgical technologies are therefore potentially much superior to pyrometallurgical alternatives for HBMS.

From an R&D standpoint, the first priority for HBMS is to carry out the required pilot scale testwork to verify the technical feasibility and economics of the zinc pressure leach process. As mentioned earlier modifications to the zinc pressure leach technology now in place at Cominco, Trail and Kidd Creek, Timmins are required in order to adapt the process to the HBMS operation. In addition the need for a zinc fuming plant in the new flowsheet must also be assessed. HBMS officials estimate that once initiated, the required development work would take about two years at a cost of some \$C 5 million. This work will likely be carried out jointly with Sherritt Gordon who are leaders in the development of pressure leach processes for the treatment of base metal sulfide concentrates, with the production of byproduct sulphur.

Copper chloride leach technology is not as advanced as zinc pressure leaching. Required development work is estimated to take at least two years at a cost of approximately \$C 20 million. For HBMS, its R&D program should ideally achieve the following objectives: obtain 98 per cent recovery of copper as a high purity product, without electrorefining;

recover at least 95 per cent of the silver in the copper concentrate as a high grade silver bullion; recover gold and silver in both CCL process and ZPL process leach residues; and integrate CCL and ZPL processes to ensure recovery of zinc in copper concentrate and copper in zinc concentrate. In addition the recovery of saleable elemental sulphur from leach residues should be verified.

Provided test work proves successful, it is estimated that the copper chloride leach process could be implemented at a cost of \$C 130 million (1982) and yield a pretax discounted cash flow rate of return of about 20 per cent.

In conjunction with the above projects, HBMS should also continue work to develop improved mineral beneficiation techniques to facilitate zinc-copper separation in selective concentrates and to improve zinc, gold, silver recovery from HBMS ores.

Falconbridge

The high priority R&D areas for Falconbridge research and development are improved pyrrhotite rejection, continuous converting and increased roasting and converter slag cleaning.

Provided metal losses can be minimized and developed ore reserves are available, increased pyrrhotite rejection can significantly reduce SO₂ emissions, while maintaining overall plant productivity. Research and development costs would be about \$C 7.0 million over a 3- to 5-year period.

Continuous converting could lead to greater than 95 per cent capture of SO₂ gases in the smelter, while at the same time improving productivity and working conditions. This would be a good long-term objective for the Falconbridge smelter. Research and development cost is estimated at \$C 15 million. Research and pilot plant work would take 4-to 5-years.

Increased degree of roast in the Falconbridge smelter from the present 56 per cent level to higher levels would increase the degree of SO₂ capture. R&D is required to identify the best operating conditions and to minimize metal losses in the smelter. This approach will complement the work on continuous converting and further increase the productivity of the smelter. Cost of this work is estimated at \$C 7 million over a 4- to 5-year period.

Converter slag cleaning development to reduce metal losses is essential to ensure the economic viability of both continuous converting and increased degrees of roast in the Falconbridge smelter. Research and development cost is estimated at \$C 7.0 million over a 4- to 5-year timeframe.

Over the longer term, research and development into new improved pyrrhotite processing methods should be undertaken. This work could be jointly undertaken with Inco. Total cost is estimated at \$C 10 million.

Noranda Horne

The priority at the Horne must be to maintain and further improve the productivity and flexibility of the smelter operation, while at the same time achieving major reductions in SO₂ emissions. The Noranda reactor has much lower smelting costs than the reverb furnace. Therefore significant productivity improvements could be gleaned by optimizing the throughput of the reactor in order to minimize reverb furnace usage. This could be accomplished by developing pretreatment technology for complex concentrates, which is compatible with the reactor.

Reactor efficiency could be further improved if present supplementary fuel requirements were eliminated. Autogenous operation of the reactor could be achieved via increased oxygen enrichment. Problems that would have to be overcome for autogenous operation include slag-matte separation, refractory wear and tuyere gas blowing requirements.

If air infiltration can be controlled, autogenous operation of the reactor could also result in a high strength SO₂ gas stream (>25 per cent). This would permit SO₂ control via new fluid-bed acid plant technology. However, significant pilot work and a major test program are required to achieve low air infiltration and demonstrate the technical and commercial viability of this acid plant technology. Nonetheless if this technology is proven, the costs of SO₂ control could be reduced considerably. Indeed, compared with conventional acid plant technology, the capital and operating costs savings could approach 50 per cent or more. It should also be noted that some improvement in SO₂ control could also be achieved, particularly if the proportion of plant throughput to the reactor can be increased.

Other R&D projects that could lead to improvements in plant productivity, workplace environment and/or SO₂ emissions include: the development of a continuous copper converting process; a process for the treatment of smelter dusts; and, the development of lower cost copper refining techniques.

Total expenditures associated with the above R&D projects could approach \$C 80 million. A three- to seven-year program will likely be required to carry out all of the above projects.

SUMMARY COMMENT

A number of promising new and/or modified technologies have been identified for each plant, which, if proven technically and commercially viable could increase productivity and/or make pollution control more affordable. In some cases, longer term technological alternatives could offer more attractive solutions from both an economic and environmental standpoint.

It is estimated that many of the new and/or modified technological alternatives could be developed and demonstrated within a 5-year period or less. If testwork proves successful, commercial scale implementation of these technologies for most plants could be achieved by 1994. Moreover, the time spent in finding optimal technological solutions would provide companies an opportunity to restructure their balance sheets and to stabilize their position in the international marketplace.

TABLE 8.1
Extraction/Refining R&D Projects for Canadian
Nonferrous Smelting Industry

Project	Company	Estimated Total Cost (\$10 ⁶)	Time Frame (years)
1. Continuous converting process for copper (some engineering included)	Inco Sudbury	25	5
	Noranda	15	3-5
2. Flash smelting continuous converting process for nickel (some engineering included)	Inco Sudbury	35	5-7
3. Improved (modified RRS) roasting/electric smelting process for nickel (some engineering included)	Inco Sudbury Falconbridge	15 7	2-3 4-5
4. Improved pyrrhotite rejection process for nickel concentrates (engineering included)	Inco Sudbury Inco Thompson Falconbridge	12 7	3-5
5. Improved electrorefining process for copper (engineering included)	Noranda	15	5-7
6. New electrorefining (or electrowinning) process for nickel from nickel sulphide	Inco	10	3-5
7. Continuous converting process and converter slag cleaning from roast electric smelt process	Falconbridge	22	4-5
8. New acid plant technology for high strength SO ₂ gases (engineering included)	Noranda	5	2-3
9. Pressure leach process for zinc (engineering included)	HBMS Sherritt Gordon	5	1-2
10. Chloride leach process for copper	HBMS	15	2-3
11. Process for gold and silver recovery from leach residues	HBMS	5	2-3
12. Autogenous operation and air infiltration control of Noranda reactor for copper smelting	Noranda	7	3-5
13. Process development for treating complex copper concentrates	Noranda	27	3-5
14. Treatment of slimes from copper refining	Noranda	10	3-5
15. Improved milling-beneficiation techniques for increasing gold and silver recovery in copper, zinc concentrates	HBMS	5	3-5
16. Alternate sulphur fixation technologies	Inco Noranda Falconbridge Sherritt Gordon	20	3-5
17. New process for treating pyrrhotite	Inco Falconbridge	10 —	5-7
Total		272	

CHAPTER IX

CONCLUDING OBSERVATIONS

The major challenges facing Canada's nickel and copper industries are to improve productivity and international competitiveness and to effect major reductions in SO₂ emissions, during a period when companies are encountering a number of market and financial difficulties. The analysis presented in the preceding chapters suggests that the twin objectives of increased international competitiveness and pollution control are not compatible, at least in the short term. In large measure, this is due to the limitations of existing technology and problems associated with marketing large volumes of additional new sulphuric acid production. However, a number of new or modified technologies have been identified on a plant by plant basis which, if proven technically and commercially viable, could offer much scope to improve productivity and/or make SO₂ control more affordable. If test work proves successful, commercial scale implementation of these technologies, for most plants, could occur within the 10-year timeframe recently established by federal and provincial environment ministers.

Because of the market and financial circumstances facing Canadian nickel and copper producers, major economic dislocations could result depending upon the timing of regulated emission reductions for nonferrous smelters. If major reductions are required before the early 1990s, there may be a requirement for new programs of capital and other forms of assistance to help offset the economic, and in some cases technical, shortcomings of existing technologies. In this manner the international competitive position of the industry would not be undermined or jeopardized in the pursuit of environmental objectives.

Alternatively, if emission reductions from nonferrous smelters are not required until 1994, government initiatives to encourage the development and demonstration of promising new or modified technologies could be a logical first step. The time spent in finding optimal technological solutions would provide companies an opportunity to restructure their balance sheets and to stabilize their position in the international marketplace. Although this approach would not preclude the possible need for some capital assistance at a later date, it could offer the most cost-effective route to achieve the twin objectives of increased international competitiveness and pollution control in Canada's nickel and copper industries.

The timing and apportionment of SO₂ emission reductions among industries and establishments to meet stated environmental objectives has yet to be determined. In developing an approach to achieve desired environmental goals, it is clear that decision makers will need to carefully consider matters related to market, financial, technical and byproduct sulphur issues. This will not be an easy task. It is hoped that this document will provide a useful basis and a first step towards the development and implementation of an overall strategy that will permit the timely resolution of both the economic and environmental problems facing Canada's nickel and copper producers today.

